Igniting University Communities: Building Strategies that Empower an Energy Transition through Solar Energy Communities

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Universities as centers for innovation by nature can play a relevant role in serving as education hubs for citizens in energy, promoting individual and collective behavioral changes among community members. By collaborating with their own communities on the energy transition, universities can become more sustainable while providing firsthand experiences that can trigger new attitudes in their students and employees. In this framework, this article explores ways to create partnerships to establish energy communities and promote shared photovoltaic energy facilities in an inclusive manner, emphasizing the social impact of such actions. Four public universities in Aarhus, Évora, Ljubljana, and Madrid are challenged to explore the avenues for turning this vision into reality. In this article, the entire exploratory process is described and the various barriers encountered are highlighted.

1. Introduction

Communities of energy in different shapes and models have been part of the power system since the last century,[1] their regulatory development in Europe has been an important step toward promoting a more sustainable and participatory energy system. The clean energy for all Europeans package (CEP)[2]—a set of eight legislative acts on the energy performance of buildings, renewable energy, energy efficiency, governance, and electricity market design—recognizes certain categories of communities as *energy communities*; specifically, Directive (EU) 2018/2001, on the promotion of the use of energy from renewable sources—known as Renewable Energy Directive II (REDII)—which develops the framework for *Renewable Energy Communities (RECs)*,[3] and Directive (EU) 2019/944 on common rules for the internal market for electricity, which develops the framework for *Citizens' Energy Communities (CECs)*.[4]

Energy communities[5] refer to the groups of citizens, businesses, and other entities that engage in the production, consumption, and distribution of renewable energy at the local level. These communities allow participants to share and trade sustainably generated energy, fostering the transition toward a more decentralized and clean energy system.

Many European countries have adopted specific laws and regulations that transpose these norms. They address issues related to the ownership and access to the grid, accounting for produced and consumed energy, as well as compensation and remuneration mechanisms for participants. Technical and administrative requirements are also established to ensure the safety and efficiency of energy community operations.

These regulations assume that energy communities have a primary purpose of sharing not only economic but also environmental and social community benefits among citizens. In line with such arguments, we consider a commendable and implicit goal to view an energy community as a tool to achieve such benefits within a local community, rather than constituting a traditional community of energy under the new form of an energy community, where economic objectives prevail although the other benefits infer from them.

In this context, we wonder to what extent the energy communities built on top of large social communities could serve as an instrument to achieve inclusive education on green and sustainable energy habits. These local energy communities would serve as hubs to both promote behavioral changes in energy habits

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through citizen–science actions and allow all citizens to take part in the energy transition regardless of their income level and type of household. In fact, solar energy via solar rooftop self-consumption schemes has been successfully implemented as a strategy to improve energy access in low-income communities.[6,7] Within this context, the engagement of the public sector to activate and promote such hubs seems to be crucial in the following terms.

1) Establishing and supporting energy communities:[8,9] the public sector can facilitate the creation of local energy communities by providing resources, infrastructure, and policy frameworks that enable their formation. These communities can bring together individuals from diverse backgrounds and provide a platform for collaborative learning and engagement in sustainable energy practices.

2) Promoting citizen-science initiatives:[10,11] the public sector can actively promote citizen-science actions within these energy communities. This can involve organizing workshops, training sessions, and awareness campaigns that encourage citizens to participate in data collection, analysis, and research related to green and sustainable energy habits. By involving citizens in the scientific process, these initiatives can enhance their understanding and empower them to make informed decisions regarding energy usage.

3) Ensuring accessibility and inclusivity:[12,13] the public sector should strive to make these energy communities inclusive and accessible to all citizens, regardless of their income level or household ownership. This can be achieved by addressing barriers such as affordability, language, and digital literacy. For example, providing financial incentives, offering educational materials in multiple languages, and ensuring access to technology and digital platforms can help overcome these barriers and ensure broader participation.

4) Promoting education on energy transition :[14–17] through their schools and universities, the public sector can integrate inclusive education on green and sustainable energy habits into formal curricula. This collaboration can help educate future generations about the importance of sustainable energy practices and empower them to become active contributors to the energy transition.

5) Policy support and incentives:[18,19] the public sector can develop supportive policies and provide incentives to encourage citizen participation in energy communities. This can include financial incentives for renewable energy installations, grants for community projects, and regulatory frameworks that prioritize community-led initiatives. By creating an enabling environment, the public sector can motivate citizens to actively engage in sustainable energy practices.

In summary, by actively engaging the public sector to activate and promote local energy communities, which incorporate citizen-science actions, inclusive education on green and sustainable energy habits can be achieved.

Therefore, in this work, we discuss the work carried out for over a year and a half to formulate models of communities of energy adapted to European universities, exploring from novel energy communities to more traditional self-consumption structures. In the present day, most energy communities are incorporating municipalities and even public schools. This has prompted us to contemplate how other entities, like those consisting of almost 5000 higher education institutions in Europe, could also encourage the energy transition in collaboration with their respective communities. This involvement would entail collective efforts to promote behavioral changes in energy consumption. The tertiary educational sector encompasses around 17.5 million students, with the support of 1.35 million educators and 1.17 million researchers.[20] By considering medium-sized facilities with a target of 200 kWp per participating institution in Europe, we could reach 1 MWp of solar photovoltaic energy per every five organizations replicating the model. And most importantly, involve their students, professors, researchers, and other staff in promoting sustainable actions and building new knowledge about the impact of their energy decisions. Assuming an equal distribution of people among the 5000 higher education institutions, these figures indicate that if we establish energy communities in 10% of such higher institutions and 20% of their community members are willing to participate in the hub, there would be around 400 000 citizens across our hubs. This way we could collectively install new photovoltaic power of 100 MWp co-owned by 80 000–100 000 citizens in 500 new energy communities. This statement is based on our recent study on the acceptance of this idea in public universities, where out of almost 300 respondents, about 20%–24% of them chose investment in the facility as their preferred activity when participating in the hub.[21] A recent study highlighted that there are 4000 energy communities in Europe, encompassing 900 000 participants.[22] This suggests that, on average, we would have the potential to engage with university communities with the current average engagement rates shown by the energy communities and promoting new niches for energy communities to be implemented. Hence, the potential of the tertiary educational sector in the citizen's empowerment mission is sufficient to delve deeper into the study. Therefore, we have been focusing on how to model strategies for igniting solar communities in European public universities.

2. Methodology

The main objective set by the researchers in this work consists of allowing any citizen to be part of the energy transition regardless of their investing capacity, whether they own a house or not, and their educational level. In this way, and always accompanied by other members of the community, they will participate in actions that facilitate firsthand experiences, including those related to energy generation and self-consumption via the constitution of a community of energy. The overall rationale is depicted in **Figure 1**.

This rationale implies that a promoting group within a large social community starts to communicate and test the idea within their own networks in each community. Certainly, as described by Rogers in the diffusion of innovations theory,[23] a group of early adopters will adhere to the innovative idea, soon representing around 13.5% of the community. This way, an informal structure is constituted as a hub of citizen science.

Our research study was conducted at four universities: the Technical University of Madrid, UPM, Spain; Aarhus University, AU, Denmark; the University of Évora, UEVORA, Portugal; and the University of Ljubljana, UL, Slovenia. Considering 5000 people as the average size of the communities targeted by the authors (which is not the entire university community but the faculties and schools within a geographical area), our citizen energy hubs should engage around 675 people.

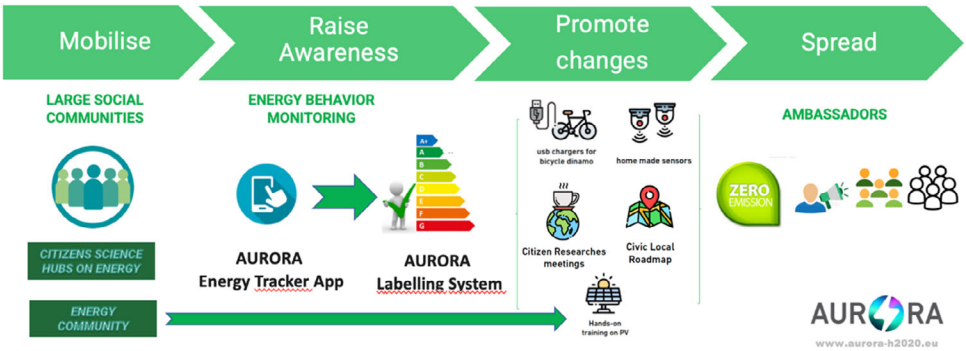

Figure 1. AURORA rationale on the citizens' engagement in the energy transition.

The first action encouraged to be performed by each member is to monitor their own energy behavior in a quantitative way via the AURORA Energy Tracker app,[24] based on a labeling system specifically developed for this purpose.[25] Once each participant is aware of their own impact on the achievement of the European energy transition objectives, firsthand experiences are offered through workshops, contests, data collection, dialogues, etc. The innovation offered by AURORA is that we also aim to provide real participation in a community photovoltaic plant specifically created and installed in nearby buildings where the hub is established.

Therefore, the use of public spaces already designated for education, such as university campuses, emerges as the best candidate for implementing the rationale. First, universities are not only spaces for education but also agents for generating innovation. Society, including universities themselves, is accustomed to predominantly discuss the role they play in technological innovation. However, given that the energy challenges we are facing require more than just technology, society must demand that universities also become centers of social innovation. Universities can act as small microcosms where not only technological solutions but also social innovations can be tested.

The formulation of the objective to be pursued is clearly established from the beginning, as the models to be explored will decisively move toward its achievement. Therefore, the reading of this article should be approached from that perspective, as certain limitations or barriers mentioned are inherent to the pursued model rather than limitations of the institutions to contribute to the energy transition with other approaches. Thus, it will be paradoxical for the reader to find that a European public university can easily engage in collective self-consumption if the action is led by the institution without third parties involved, but when the objective is to carry out a community-funded collective self-consumption, finding a viable model becomes a tortuous path.

The implementation path of a community of energy has been explored in four European universities from four different member states. The objective is to establish a formula where members of the university communities can form a citizen hub or community of energy with the legal structure required to finance photovoltaic installations. The model would allow the university to consume the electricity generated, benefiting from immediate economic savings without having to be involved in the financing. The participants' investment would be repaid through the conditions set in the power purchase agreement established with the university. By conducting crowdfunding campaigns with investments ranging from amounts less than €100 up to €3000, it would be possible to involve approximately 500 participants in each installation, making it feasible to establish a 200 kWp PV facility. All demo sites have been supported by national law firms in the exploration of the models developed here and legal experts from different universities have been also involved in the process.

Our results are presented according to the methodology described in **Table 1**. It shows a set of questions and procedures we aimed to answer when starting the research together with the universities and the hired legal teams. This methodology was created thanks to a collaborative effort to put together all the know-how from AURORA researchers and the lawyers, and it is being ratified as the final communities are set.

3. Results and Discussions

3.1. Legal Framework

3.1.1. RECs and CECs

The figure of energy communities as an actor in the electric sector and the promotion of collective self-consumption stated by the clean enegy package is recognized in the national laws of the four demonstration sites: Denmark, Portugal, Slovenia, and Spain. There are mainly two types of energy communities: RECs established in REDII—EU Directive[3] and the *CECs* set by the Directive (EU) 2019/944.[4]

The regulatory treatment of CECs and RECs is differentiated based on the directives that govern them. CECs are specifically recognized as market actors in the recast Electricity Market Directive, particularly in Article 16. Its primary objective is to ensure a level playing field and fair competition for CECs within the energy market. The Electricity Market Directive focuses on establishing the necessary conditions and regulations to enable CECs to participate and operate effectively. In contrast, RECs are governed by the REDII, specifically in Article 22. The REDII updates the framework for promoting energy derived from renewable sources. Under this directive, member states are mandated to create a supportive regulatory framework that aligns with the provisions relevant to different activities within the

Table 1. Factors to explore in the preparation of the communities of energy.

LEGAL FRAMEWORK
1. Description of the main laws or directives affecting the creation of the Local Energy Community. If public bodies will become members of the community, define how this is affected from a legal perspective.
2. Description of the process in your region to create the local energy community.
GOVERNANCE
1. Goals of the community: considering that the main goal should not be profitability but to get environmental and social benefits, some tentative missions—nonexclusive—could be as follows. a. Generation of renewable energy for self-consumption in the university b. Provision of clean energy for electric cars c. Contribution to citizen science missions d. Generation of climate ambassadors e. Awareness and education on energy aspects f. Contributing to the local social impact by addressing energy poverty, etc.
2. Legal form of the community considering that local energy communities should follow the principles of democracy, open participation, independence, and autonomy. a. Limiting to the participation of members of the community (individuals, local associations, SMEs, local administrations). b. Management and decision-making of the community: ensuring transparency and accessibility to data, who can be in the Board, IT tools, administrative support, etc. c. Types of participation: in-kind, in-cash, etc. Sometimes, a small contribution is provided to take part in the community and there is a differentiation between "legal property" and "symbolic property". d. Type of participation: fixed, flexible, etc. Is there any limit to the economic provision by members? e. Requirements for accessing/leaving the community. f. Monetary management: shares, loans, participatory accounts, donations, etc.
3. Documentation according to the legal form: statutes, internal norms, etc.
4. Management of contracts to formalize the participation.
5. Additional deals such insurances coming from matters related to maintenance and liability.
6. Electricity management (self-consumption, sale).
7. Documentation to formalize key agreements with the public entity such those requested to set maintenance and liability or the electricity purchase cost if they can buy it, etc.
ENGAGEMENT
1. Acceptability by the targeted audience.
2. Engagement process: targeted audience, events, provision of information, etc.
IMPLEMENTATION
1. Viability scenarios: demand vs. installed capacity. Available locations—public/private.
2. Financial planning.
3. Cost for the project (including maintenance) + local/national grants support.
4. Return of investment (ROI)—benefit—to the energy community members (profits, in-kind contributions, local discounts, etc.). Description of the process to manage such ROIs.
5. Additional benefits, i.e., reduction on taxes due to buildings, and reduction on the "fixed" power capacity contracted.
6. Technology to be installed.
7. Additional impacts requested for the installation, i.e., for research processes or integration in universities courses.

renewable energy sector, such as suppliers and aggregators. The goal is to promote and facilitate the development of RECs, providing a conducive environment for REC projects to thrive. While CECs focus on establishing a fair competition within the energy market, RECs aim to promote and facilitate the development of renewable energy projects through a supportive regulatory framework. Both directives play crucial roles in promoting sustainable energy practices and community engagement in the energy transition.[26]

CECs and RECs are legal entities established with the purpose of promoting sustainable energy practices. However, there are some key differences in how these communities are defined.

CECs are characterized by being effectively controlled by their shareholders or members, who are typically citizens or residents. Their primary objective is to generate environmental, economic, and social benefits for the community, prioritizing the well-being of the members and the local environment over financial profits. In contrast, RECs are focused specifically on renewable energy generation and consumption. They may involve a broader range of stakeholders, including individuals, businesses, and organizations necessary to set up the project. The emphasis of RECs is on promoting the development and use of renewable energy sources, aiming to reduce carbon dioxide emissions and contribute to the transition to a more sustainable energy system.

While both CECs and RECs share a common goal of promoting sustainable energy practices, the specific definitions, and requirements for each type of community may vary depending on the legal framework and regulations in different jurisdictions. In this regard, we found the following legislation applicable to our demonstration sites.

In Portugal, both Energy Directives 2018/2001 (REDII) and 2019/944 have been adopted under the Portuguese decree

no. 15/2022 of January 15, 2022 to promote and facilitate the self-consumption of energy and RECs, creating conditions for the establishment of innovative economic and social solutions benefiting of new technological opportunities.[27] Decrees nº 153/2014[28] and nº 162/2019[29] are regulating self-consumption activity.

In Denmark, RECs and CECs were incorporated into Danish law by the Electricity Supply Act (lovbekendtgørelse, or LBK, nr. 984 of 12/05/2021)[30] and the Act on the Promotion of Renewables (LBK nr. 1791 of 02/09/2021).[31] The provisions on energy communities are detailed in the executive order on RECs and CECs and the relationship between RECs and CECs to electricity trading companies and collective electricity supply companies (bekendtgørelse, or BEK, nr. 1069 of 30/05/2021).[32] Additionally, the executive order on net settlement for self-producers of electricity (BEK nr. 2657 of 28/12/2021)[33] and executive order on renewable energy prosumers (BEK nr. 857 of 20/06/2023)[34] provide further framework applicable to production, consumption, storage, sale, and share of renewable electricity within a community of renewable energy self-consumers.

Slovenia transposed the Renewables and Electricity Market Directives, including most provisions on energy communities in July and October 2021 with the Acts n° 2570 on the promotion of the use of renewable energy sources (ZSROVE)[35] and n° 3349 on Electricity Supply (ZOEE).[36] They further rely on the older Cooperatives Act (ZZad).[37]

In Spain, currently, there is no specific law that regulates CECs in compliance with the European Directive 2019/244 or RECs in compliance with the European Directive 2018/2001. The definition of RECs is transposed, but the enabling framework, particularly from a regulation perspective, is still pending. Self-consumption is regulated in Decree 244/2019[38] and Law 24/2013[39] of the electricity sector.[40]

When exploring such legislations and delving into energy communities' membership, it is found that both EU laws involve public sector participation through local authorities, and include municipalities in REDII.

"Natural persons, local authorities, including municipalities, or small enterprises and microenterprises, provided that for private undertakings their participation does not constitute their primary commercial or professional activity".

The local authority is defined in the context of governance and administration of a specific geographic area, such as a municipality, city, county, or region. The local authority refers to the set of powers, functions, and responsibilities granted to a local government to make decisions and exercise control over matters that affect the community within its jurisdiction. Its precise definition may vary depending on the country and its system of government. Generally, local authorities have competencies in areas such as urban planning, public transportation, waste management, provision of local services (such as water, sewage, and public lighting), maintenance of local infrastructure, economic promotion, and community welfare. For instance, in Spain and Denmark, they are also responsible for managing schools.

During our research, we have observed that the lack of development in regulations regarding the definition of a local authority has created much uncertainty for universities, which understandably adopt a conservative approach in their actions. Universities depend on the national or regional government and are hence not considered *local authorities*. Although our legal teams have made efforts to provide explanations as to why universities can be considered *local authorities* for the purposes of transposing the referred European Directives, there was not an agreement on the role of the universities. Some arguments stated by lawyers in Madrid to a defense that universities could be considered *local authorities,* which is the term in the RECs definition transposed, were the following:

*"the UPM – Technical University of Madrid- should be considered as a local authority. Starting with the latter, which is the consideration of "**local**" we can conclude that the local characteristics of the UPM are not in doubt. In this regard, the University is part of the network of local entities and has an impact on the city of Madrid as well as the surrounding metropolitan area. As for the consideration of the University as an **authority**, considering the purpose of EU Directive 2018/2001 and the overall European legal framework on energy transition and combating climate change, through a teleological interpretation, we can understand that the University, as a legal entity within the public sector, should be considered as an authority for these purposes".*

"Likewise, the fact that the directive has stated "local authorities, including municipalities" implies that the consideration of a local authority is not limited to municipalities and their city councils, as they are part of the concept of a local authority, allowing for other legal entities to be considered as such. Similarly, public universities are included, along with entities that make up the local administration, within the public sector in Article 2 of Law 40/2015, of October 1, on the Legal Regime of the Public Sector (hereinafter referred to as the "LRJSP")" Legal Advisor hired by the researchers.

But the legal position of the Technical University of Madrid states that according to the Law 7/1985 of the Spanish Local Entities, universities are not on the list of *local entities*. This confusion between *entity* and *authority* is an additional difficulty beyond the "*local*" character. Spain has not transposed the EU Directive yet, but the Spanish Ministry is funding the constitution of energy communities through public calls.[41] The university managers could only evaluate the definition mentioned in such public call, which referred to *local entities*, instead of *local authorities*.

This fact presents a challenge for universities in forming any type of legal energy community. We strongly encourage the policymakers to clarify the terms on which the energy communities' directives must be applied in this regard. However, although it was disappointing, this fact did not prevent the project from constituting a community of energy out of the formal concept of energy communities.

Energy communities are figures recognized after several decades of energy citizen-led energy initiatives.[42] The new directives open the door to citizens acting in all the power sector: Electricity generation, distribution and supply, consumption, aggregation, storage or energy efficiency services, generation of renewable electricity, charging services for electric vehicles, or providing other energy services to its shareholders or members; or even in all the energy sector (REDII). Thus, going back to the objective of our research, aiming for people to have firsthand experiences with renewable energy to later promote individual behavioral changes, we consider that electricity generation and consumption are the two activities that could provide useful education for a standard citizen. So, our hubs can be

formed to provide experiences on self-consumption where there are clearer regulations.

3.1.2. Models for (Collective) Self-Consumption

Self-consumption has been a well-established concept for several years, with individual consumers utilizing the energy they generate on-site. This practice has been prevalent in many member states. However, recent developments in the sharing economy and the increasing financial feasibility of self-consumption have sparked interest in direct electricity sharing between producers or self-consumers and other end users. The "Clean Energy for all Europeans" package (CEP), initially published on November 30, 2016, represents a significant milestone as it recognizes collective self-consumption in EU-level legislation.[2] Self-consumption (collective) is indeed better regulated in all EU member states than RECs or CECs. Collective implies that there are several consumption points—electric counters—consuming from the facility regardless of their ownership.

Hence, the most viable legal framework for facilitating the establishment of solar communities in collaboration with European universities appears to be centered around the regulations governing self-consumption or collective self-consumption. Essentially, this entails a combination of laws that enable citizens to form cooperatives or other legal entities, secure financing for renewable installations, and operate as a business, with the ability to sell surplus energy back to the grid. Additionally, there are specific regulations concerning self-consumption, particularly in the realm of shared or collective self-consumption. These regulations allow for the implementation of "crowdfunded facilities," to cater to the energy requirements of all or some members of the cooperative before considering the option of selling any excess energy.

In this regard, although we cannot strictly adhere to the concept of an energy community, we researched if the university community could act as a classical citizen-led initiative, but we adopted some of the operating principles of RECs defined in Article 71 of REDII. 1) Encouraging open and voluntary participation to the greatest extent possible, ensuring that the community is autonomous and effectively controlled by shareholders or members who are near the renewable energy projects owned and developed by the legal entity. Participation in the project should be open to all potential local members based on objective, transparent, and nondiscriminatory criteria. 2) The shareholders or members of the community can be natural persons, small- and medium-sized enterprises (SMEs), or authorities. It should be noted that for our model authorities, while not strictly bound by the legal definition, are nonprofit entities recognized by the community and acting locally. 3) The primary purpose of the community is to provide environmental and social benefits to its shareholders or members and the local areas in which it operates, prioritizing these benefits over financial profits. Thus, the educational perspective of citizens is the main driver.

3.1.3. Implementation in the Universities

During the first six months of the project, Aarhus University, AU; University of Évora, UEVORA; University of Ljubljana, UL; and Technical University of Madrid, UPM collaborated with their legal advisors to develop a suitable business model tailored to the specific circumstances of each location. At that stage, we became aware of the numerous challenges that lay ahead for including universities in the constitution of the communities. The first step addressed was to find a legal figure to constitute the public–private partnership of the university members and the university in an educational hub capable of carrying out firsthand experiences in energy, including the generation and consumption of renewable energy.

Cooperatives: Considering the tradition of solar cooperatives leading the citizens-led initiatives in Europe, our first attempt was the creation of a cooperative with different results.

In Slovenia (applies for the UL), cooperatives are the unique possibility for enabling a community of energy according to their legislation. There, we found an impediment in Article 10 of the Higher Education Act,[43] which is currently the subject of a legal dispute between faculties and universities, that prevents faculties or universities from establishing or co-establishing any new legal entity. Additionally, the explicit approval of the Government of Slovenia is required.

The cooperative model also raised concerns to UEVORA and UPM. The cooperative model is a legal structure designed for commercial objectives and universities do not have among their purposes achieving. Therefore, they cannot have financial products offering interest or payments resulting from capital income to participants or having outgoing cash flows. In Évora, they were also exploring with the former administration team the chance of offering the participants discounts on university services, but the new administration rejected the proposal, since they consider such deals as a way of in-kind "profitability".

In Denmark, the cooperative model is preferred due to its historical and cultural influence on Danish life and many successful examples of citizen-driven energy cooperatives. However, university law does not allow AU to become a member of the cooperative and gain financial profits from it. Therefore, the cooperative model is plausible, but the university may not be a member of the cooperative. In addition, AU does not own most of its buildings and rents the buildings from the State and private companies. Consequently, the students and staff of the university community will form an independent cooperative. The cooperative will rent the rooftop of one of the buildings that the university uses and crowdfund the facilities. Since the PV facilities will be set up on the same buildings where the university resides, the university will be able to purchase the electricity as a "prosumer" due to the unique "prosumer via third party" framework that is accepted in Denmark. By this approach, the university will still be involved in the community, but not in the cooperative.

Associations and Foundations: The next step explored was the chance of creating the communities through the legal figure of a foundation or an association. Foundations, like associations, have a much more flexible framework than cooperatives since they are not required to distribute profits. For instance, the participation of citizens can be considered a loan that the organization must repay.

Universities can be part of associations, but in these associations, decision-making is required to be done in an assembly-based manner. This undoubtedly puts universities in a less receptive framework since any privileges are granted to

universities as public entities, and decisions are made by the majority. In a scheme like the one proposed by the researchers where any participant can enter with a fee of less than €100, it is understandable that universities have not even considered this type of legal form. Furthermore, while cooperatives and foundations can have a public or private character, associations have an exclusively private character.

Foundations, in contrast, have a greater degree of freedom regarding the organization of votes and the management of the foundation. They can also be considered as public foundations, subject to the same rules that govern public universities. This undoubtedly favors universities in seeing foundations as a legal structure with greater guarantees.

In this scheme, both UEVORA and UPM explored this path. In the case of foundations, both in Spain and Portugal, universities have ruled out creating an ad hoc foundation for the project's objectives. There is no legal impediment, but it is true that in both countries, the reorganization of the public sector and the improvement of its efficiency have been regulated by the law, partly supervised by Europe for the receipt of European aid funds that these countries have received in the past. All sectors, without exception, including UPM and UEVORA, have been merging or eliminating foundations. As a result, at the Technical University of Madrid, the only existing foundation is the General Foundation of the UPM (FGUPM), and in the case of Évora, the restructuring has been such that they don't even have a general university foundation.

Thus, the Technical University of Madrid opened a way, once approved by the university management, to explore how the FGUPM could act as a vehicle for establishing the desired community of energy, given that the FGUPM included among its foundational purposes the promotion and conservation of the environment.

3.2. Governance

The general operational rationale of our communities has been previously described as a hub where participants will have access to firsthand experiences in energy. In this section, we discuss further details on the business models that were analyzed.

3.2.1. Decision-Making and Participation

Aarhus University establishes a cooperative that will utilize the rooftops of buildings owned by a private landlord who rents the building to the university, so decision-making will follow the general operational approach typically employed by cooperatives, i.e., one person–one vote. This approach is rooted in a democratic and participatory process that involves the active participation of cooperative members. By adhering to these principles, cooperatives strive to ensure that decision-making aligns with the collective interests and values of their members, fostering a sense of ownership and active participation within the cooperative. The cooperative model will not limit participation to external citizens outside the university community but due to the inherent objective of our approach to operating as an educational hub in the university framework, it is understandable that strong communication campaigns to gain adepts in the Aarhus University campus are performed.

As for the Technical University of Madrid, the proposed scheme explored within the foundation involves establishing the community as a commission within the FGUPM, although it won't have legal recognition as an independent entity. All the existing rules and provisions that are already in place for the foundation, including those outlined in the new Operational Regulations of the Commission, will not be altered by this arrangement. The model clarifies that the commission would have solely operational functions, and any decision made would be a mere proposal to the board of trustees of the FGUPM, who would have the final say. This model is more restrictive compared to a cooperative, but it ensures that the foundation maintains control over something that, due to its inherent innovative nature, raises doubts and reservations. The commission will be managed by representatives of the students, professors, and staff. Individuals belonging to the university who provide financial support to the commission will be considered members.

3.2.2. Funds Provision

In Aarhus, participants will access the cooperative with shares from €100 up to €3000. After evaluating several local crowdfunding platforms, it was decided to organize crowdfunding in the form of bank transfer, because crowdfunding platforms cannot provide the required support (i.e., being able to distribute yearly financial returns to crowdfunders in the long term) or require unnecessary procedures to set up a separate organization. As a result, the crowdfunding will be done through bank transfer (facilitated with the use of a mobile payment application), the same way as what the other Danish energy cooperatives have done in the past.

In Madrid, the proposed financing method was presented in two alternatives: participatory accounts and loans. From an accountability standpoint, participatory accounts may prevent the institution from ensuring a defined profitability for the participants. However, there were some concerns about this mechanism since it seems to be more suitable for private businesses. Moreover, it involves certain procedures that do not ensure the full transparency required by a public foundation. Therefore, the loan mechanism was also prepared with the peculiarity of ensuring that no debts are incurred within the FGUPM.

From the perspective of the foundation, it is important to demonstrate that they do not have a financial benefit in the operation. The general operating principle is that the university entrusts its own foundation with the responsibility of generating a portion of its electricity consumption through renewable sources. This approach allows the university to reduce costs, obtain environmental benefits, and pay the FGUPM for the electricity consumed at a fixed price. The funds received by the foundation are used to cover operational costs and repay the loans, without generating any profitability for the foundation.

At that stage, the two UPM business models were sent for evaluation to the regional government section in charge of surveilling the foundation's activities. Unfortunately, they dismissed the implementation based on two allegations. The first reason assumes that a foundation with 100% public participation requires its assets to be exclusively publicly owned or contributed, which would prevent the inclusion of private sources of

funding as proposed. The second reason, as stated in their report, is that according to Spanish regulations, the university is obligated to seek assurances from the foundation regarding the availability of adequate material and personnel resources to fulfill the purpose of the mandate. The need for private resources indicates their inability to meet this requirement.

This report made the university conclude any interest in continuing the process of looking for a legal form of a community of energy via the General Foundation. However, external legal advisors think that the report approach is more based on an opinion than on legal criteria discussing that, e.g., *"the report is confusing external financing with external capitalization of a foundation," "nothing in the laws is preventing foundations from using commercial funding systems," "in terms of a determinative question to whether the General Foundation of the University can finance itself through third parties, however the report doesn't provide a clear solution".*

3.2.3. Power Purchase Agreements

The way in which a university can access the electricity of the communities without being subject to the public energy tendering processes was another workhorse when defining the models since public bodies must be subject to public purchase mechanisms. This has been solved in the following ways. 1) In Denmark, Danish law enables the "prosumer via third party" mechanism. This implies that due to the close vicinity of consumption and production, the university can directly buy such electricity from the cooperative, avoiding any public tender. Currently, we have found that electricity taxes still apply to the prosumers in the prosumer-via-third-party framework, so even though transmission and grid fees are waived, savings for the university are not as advantageous as compared to the price offered by conventional electricity suppliers. 2) In the model proposed by Madrid and later rejected by the lawyers from the regional government, the general operating rule was that the university entrusts its foundation with the task of generating part of its electricity consumption through renewable sources. The entrustment of renewable facilities allows the university to get directly their own electricity avoiding public tendering for electricity purchase. This does not prevent the university from following the legal procedures to make such entrustment to their own foundation rather than a public tendering for the installation of the facilities.

3.3. Engagement

Researchers conducted a qualitative survey within their university communities to assess various aspects of the proposed hubs.[21] One of the survey questions focused on gauging the potential interest of community members in participating in the installations. A total of 259 individuals responded to the survey.[44] Participants were allowed to weigh options among the seven provided, indicating their most likely form of participation. **Figure 2** illustrates the results, revealing that the highest number of votes went to the option of investing in the community. Our goal is to involve approximately 20% of the total staff of the university communities in the citizen-science hubs. For the specific case of Madrid, the university community comprises 5090 individuals, so our hub should adhere to around 1000 individuals which, according to the survey, would represent around 240 people contributing to the financing of the facilities. These findings align well with the number of expressions of interest received from the Madrid community, which have resulted in a tentative leverage of €140 000.

3.4. Final Scenarios Adopted for the Communities

After exploring all the key aspects together with the respective universities, we found that we were unable to establish a real partnership with the universities for an educational citizen hub that would enable the financing of a photovoltaic installation. Even if some of the models could be feasible for other universities, i.e., foundations, in this section, we explain the final alternative models that have been developed to harness the potential of university communities as hubs for fostering behavioral changes. These models are as follows.

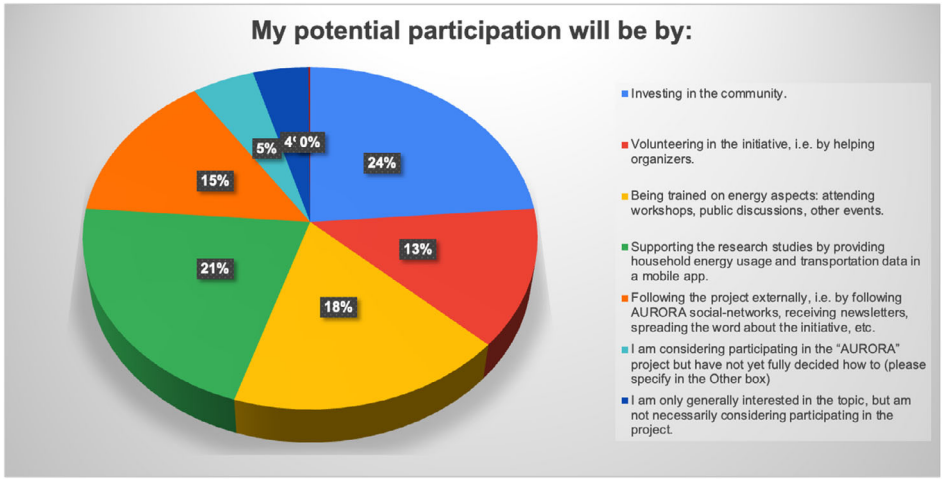

Figure 2. Potential participation of the university members.

3.4.1. Final Operational Models for the University Communities

The University of Ljubljana has established a virtual energy community through the creation of the Student Energy Club. In this model, the university itself will finance the photovoltaic installation. Club members will have the opportunity to actively participate and access all relevant information, and simulating the monetary contributions, they would have made in a traditional community setup. This alternative demonstrates the universities' commitment to finding innovative solutions when legal blocks appear even in the absence of a formal legal framework within the university structure. Leveraging their own resources to promote sustainable energy practices is commendable but we recognize that the commitment acquired by participants and the know-how acquired can be diluted in a scheme where the participants do not invest their own money.

The community of the University of Évora has forged a partnership with the Évora Red Cross, which is recognized as a local authority based on our operating principles. This collaboration aims to secure funding for an energy community that specifically addresses vulnerability situations in the city of Évora. Members of the University of Évora community have a chance to contribute financially to this project and will have the same level of involvement as expected originally despite the installation not being situated within the university premises. Considering the social impact of the project for the "beneficiary," the collaboration with such nongovernmental organization can be greater than for the universities. Furthermore, through extensive diplomatic efforts with the university management, a decision was made by the University Board to embark on a shared self-consumption installation of 750 kWp. The financing for this installation will be solely provided by the university itself—public grants requested, eliminating the need for involvement from third-party entities. This decision was influenced by the valuable insights and recommendations provided by researchers in the AURORA project, particularly regarding the technology required to ensure the preservation of the university's heritage, including UNESCO-protected buildings, described in the original plans presented to form the community of energy.

The team at Aarhus University has registered the cooperative Universitetets Energyfællesskaber after finalizing all arrangements with the owner of the university building and the university for electricity consumption. The Technical University of Madrid is currently in the process of forming a cooperative with its university members. This cooperative is set to potentially engage in two distinct installations.

On one hand, the university has made strides in establishing an agreement with the Hall of Students, located within the campus and owned by a third party. The Hall of Students, a globally recognized project awarded through the Reinventing Cities Competition, aligns its objectives with ours. In a similar scheme to Aarhus, the cooperative has an agreement with the owner of the building to install the facility there. Notably, Spain lacks any legal exceptions permitting the university to purchase this electricity, necessitating direct consumption by the building. At the moment, the Hall of Students and the cooperative of the UPM community are currently negotiating critical aspects such as the price of electricity and return on investment. The model being implemented implies that ownership of the installation resides with the energy community and will be transferred to the student housing once the expected return has been achieved.

On the other hand, the cooperative is exploring collaboration with a local school that caters to children with special needs. This partnership will utilize a portion of the funds obtained from the university's crowdfunding efforts to establish a photovoltaic installation at the school, involving families and other members of the school community. The school will then purchase the electricity for self-consumption.

3.4.2. Technical Scenarios

The project initially proposed 200 kWp power plants for each demonstrator. Some limitations arose during the research of the possible implementation, including premises, legislation and funding, all of which in some cases limit the planned size at the current stage. E.g., Aarhus University is starting with 100 kWp and will extend the installation according to available funding, and University of Evora is limited to around 45 kWp due to tight space on the Red Cross building. However, possible expansions were also identified. E.g., in Madrid, the identified roof potential to above 500 kWp, and similarly in Ljubljana, taking into account the facades and parking spaces, the potential is over 400 kWp.

Initial business plans considered 200 kWp power plants and the energy production and consumption studies were done based on this power. Since all hosting buildings have many storeys and/or high electricity demand, a 100% (or very close to) self-consumption in the buildings was predicted. This is also crucial for the business models, since the electricity value offset by self-consumption is larger compared to the one that would be obtained in the market.

To secure the business plan, proper insurance must be obtained for the power plants, at minimum consisting of liability and general risks (fire, weather events), and preferably also profit loss. Aarhus insurance was already investigated, and the estimated cost for insurance for their specific installation accounts for around 1% of the initial investment cost per annum.

From technical and technological research perspectives, we are striving for all the sites to 1) install some identical modules to enable production and performance comparison between different sites, as well as 2) to install modules of different technologies to enable evaluation of performance of different technologies. The actual realization of these two goals will highly depend on local market availability of the modules and on the installer's willingness to install modules other than the ones that they have in stock. This may at first sight look like exaggerated risk, but at current times and at several demonstrator sites some installers already refused to undertake legally or technically demanding projects because of sufficient work on other, easier, and more lucrative projects **Table 2.**

4. Discussion

The European and national policies of its member states emphasize the need for innovative solutions to expedite the energy

Table 2. Summary of the energy communities main details.

Concept		AU	UPM	UEVORA	UL
Governance	Legal form	Cooperative	Cooperative	Cooperative	Student club
	Partnership	Nobelparken building's owner	Hall of Students owner at UPM Campus Sur.	Red Cross	N/A
	Electricity management	University consumption—power purchase agreement (Danish exception)	Building self-consumption; power purchase agreement	Building self-consumption; power purchase agreement	Building self-consumption
Potential Engagement[a)]	Students	31 960	4219	8060	1000
	Staff	11 656	516	1124	350
	Total	43616[b)] (130 interested-confirmed)	4735 (404 interested-confirmed)	9184	1350
Facility	Technology	Facilities are also considered as living labs for education and research. The same technologies will be installed with same monitoring system provided by Qualifying Photovoltaics (QPV) company to provide users insights on technology differences: passivation emitter rear contact cell (PERC), tunnel oxide passivated contact (TOPCon), interdigitated back contact (IBC), and heterojunction technology (HJT). Additional technologies can be implemented in each location to cover the full power.			
	Installed power [kW]	100	200	45	200
	Annual energy production [MWh]	93	369	65	220
	Rate of self-consumption	98%	95%	100%	100%

[a)]Engagement processes are just beginning from middle September 2023. Data as for October the 6th, 2023. [b)]In the case of Aarhus University, details on the users and potential audience at Nobelparken are unknown. Figures provided are those for the whole university at different locations.

transition and motivate citizens to take climate action. This research explores the feasibility of utilizing university communities as educational hubs to drive behavioral changes at both individual and collective levels, while ensuring nondiscriminatory access for all community members. While it is not inherently necessary to establish a legal framework for these hubs to achieve the desired objectives, such a formulation has been explored due to its numerous benefits outweighing the drawbacks. On one hand, having a legal structure instills a greater sense of belonging and a stronger connection among participants compared to an undefined structure. On the other hand, a legal framework enables the financing of renewable installations that provide direct educational benefits with minimal investment, regardless of participants' socioeconomic status. Additionally, it involves them as active participants and pioneers in making local environmental changes.

In this regard, the researchers of this study have made considerable efforts to dissect and explore various partnership models, ultimately demonstrating that public–private partnerships with universities are unfeasible in all cases. In the case of Aarhus University, the unique condition under which Danish law recognizes the concept of "prosumer via third party" has allowed for the unlocking of a model after extensive work to implement our proposal, albeit independently of the university. In the other demonstrator cases, it becomes evident that universities exhibit goodwill by offering self-financed facilities to promote and achieve the desired goals of the hubs, but without genuine citizen involvement as in Ljubljana. This is also shown in Madrid where thanks to the university intervention, we have been able to unlock a via to create the energy community and install the collective facility in the Hall of Students, managed by a private party on behalf of the university for a long period of time. While it is true that the public sector benefits from well-established laws designed to protect it from private interests, throughout our research, we have observed, without intending any offense but rather as constructive criticism, a tendency that resembles the practices of enlightened despotism: "everything for the people, nothing by the people". In the case of the University of Évora, the hub model has been fully implemented also through a private partnership, where the university community has been directed toward funding an installation for social purposes. While commendable and a model worth replicating, it was not the initial focus of our study. The difference from the rest of the demonstrations is that the facility is not situated on the university campus.

Regarding the final objective of the project, it is true that none of our demonstrators have managed to establish private–public partnerships. However, both the Aarhus and Madrid models are possibly the best schemes, through which energy communities can initiate operations within these social hubs. This entails mobilizing the university community to transition into an energy community and engaging with the university to encourage any private entity established on campus, such as restaurants, student halls, banks, etc., to allow for installations.

Concerning AURORA's ultimate mission and rationale, it holds equal significance. People's focus does not delve into whether there is a public–private partnership or a private–private partnership, but if we allow them to participate in the energy transition on a bottom-up scheme, enabling these educational experiences around public sites.

Although there is a good willingness, universities have not been very proactive in pushing the initiatives forward, despite the excitement expressed by multiple colleagues regarding the EC initiative. When it comes to decision-making, the large size of universities and the diluted responsibilities among different employees make it extremely difficult to have an efficient decision-making process when discussing the various aspects of the model. Technical difficulties also arise when dealing with certain buildings on campus, such as "heritage buildings" whose appearance cannot be altered, as seen in Évora and Aarhus. Additionally, buildings with different energy meters require prior work with the distribution company. The emergence of numerous doubts and concerns reflects the fear of the unknown that arises when pioneering such endeavors, such as the long-term return on investments for the public administration, the responsibility for maintaining the roofs where the installations are set up, and the status of the installations after the end of the contract for future exploitation.

It is important to note that these studies are limited to our own framework of action and the current regulations in each country/region/university. In this regard, what would happen in countries where an ad hoc public–private foundation could be formed with community members? Could that potentially overcome the obstacle encountered in Madrid regarding private funding for a 100% public foundation? Are there other legal frameworks that can be explored, i.e., limited liability companies or public limited companies? Or, are universities creating a legal smokescreen to justify they do not have resources to promote this type of social innovation? It is understandable that it is easier to develop models like the one promoted in Evora or in Ljubljana where the university "*supports energy transition*" but "*the energy transition does not disturb their daily tasks*" than creating new public–private foundations or companies. Many municipalities and local entities are participating in the formation of energy communities using a cooperative model with citizens, without facing the same obstacles as the universities studied. This is the case of our project partner "The Forest of Dean Council" in the UK.

It is the mission and responsibility of researchers from other universities, at the very least, to bring awareness to this work and propose the study of such a model to their own institutions. Only when a statistically representative set of experiences is available, legislative changes can be driven to facilitate the impetus in energy transition that citizens can achieve by mobilizing their own resources to change their local environment. It is our wish to continue this work with a network of voluntary ambassadors willing to present this challenge to their university administrations.

5. Future Work

Our goal is to continue working to unlock the potential of the public sector to serve as an educational driver of firsthand energy experiences, including energy generation and self-consumption.

Our future work will explore the alternative model to requesting the universities or public bodies in general, the study and preparation of the public tendering process for acquiring PV installations with social participation and educational requirements. This would enable the university community (excluding the university itself) to formally establish a cooperative and submit a bid, just like any other company. However, creating a cooperative with university members and raising the necessary funds to meet the technical and economic solvency requirements set by the Public Administration for participation in public tenders is complex. Our initial exploration suggests that this approach would require a partnership between these citizen cooperatives and an enterprise possessing the technical expertise required in public tenders. This option does not guarantee that another consortium would not secure the contract, which means that citizens involved in the project may not necessarily belong to the university community. Despite this risk, if we can achieve that public tenders for PV installations include citizens' participation as a mandatory requirement, we will have accomplished our goal, regardless of the tender winner. Later, we could work on fine-tuning aspects of such a public tendering model to the prevalence of local people engagement. This is something requested by RECs definition in RED II: "*The shareholders or members must be located in the proximity of the renewable energy projects that are owned and developed by the Renewable Energy Community*". For instance, tenders could request the applicant to justify the social impact of the project on local people. Additional clauses could be the request by the institution for a delayed payment according to a fixed price for the electricity consumed and a small return on investment, instead of a turnkey project, which would ultimately lead us to a scheme with a lesser educational impact.

We will explore public tenders due to their potential for quick replication and the opportunity they present to establish the installation in university-owned buildings. However, we acknowledge that this approach does not constitute a true partnership, as we initially envisioned. Nevertheless, it facilitates the "use" of public assets and fosters engagement with the institution.

There is also policy work to commence regarding the observed differences in electricity consumption between the Aarhus and Madrid demonstrations. The Aarhus University can procure electricity from the community without a public tender, thanks to an exception "consumer via third parties" promoting the consumption of renewable energy sources directly installed in the vicinity. However, the Technical University of Madrid cannot access the consumption of such energy in a similar manner. While this is not required for the Hall of Students due to its sufficiently high energy demand for self-consumption, for replication purposes, we must consider that the owner of a private building on campus might engage in less intensive energy activities. Therefore, having an exception, as mentioned in Danish law, in all member states would be beneficial.

Concurrently, our efforts have entered a new stage in which we are engaging with proponents of this idea across various university communities in different European countries. We are using our own networks and also we have launched a communication campaign for looking for ambassadors. Twinning arrangements are already being considered. Our investigation is progressing toward initiating a dialogue with other university board of trustees to gather their opinions, visions, and acceptance of the feasible solutions currently available. These solutions may involve either establishing foundations or negotiating with a private supplier who has a building within the campus. Through this collective deliberation, we aim to unlock additional solutions for specific cases.

6. Conclusions

This study has explored how European public universities could promote social innovation for a faster, inclusive energy transition via public–private partnerships to finance renewable installations. The study has investigated to what extent members of university communities can come together in energy communities to finance self-consumption rooftop solar installations in universities. Four demonstrators were chosen in Denmark, Portugal, Slovenia, and Spain, where the different steps toward the formal establishment of the energy community have been analyzed. Initially, it has been observed that current legislation regarding the creation and promotion of energy communities, as well as their corresponding national transpositions, raises significant doubts about the possible participation of universities in such structures. However, since the primary focus of the study aligns with the educational needs of citizens to change their energy habits, this has not been a limiting factor. Effective first-hand education for a common citizen can be reached through energy generation and self-consumption. These activities are regulated by norms predating Directives 2019/944/EU and 2018/2001/EU.

Therefore, the work has focused on exploring in which existing legal figures could respond to this need. The fact that European legislation limits the participation of municipal entities in energy communities and that universities are typically under the responsibility of national or regional governments prevents an easy framework to create an energy community to which the universities can belong.

Self-consumption schemes ruling citizens-led initiatives from many years ago were explored. While the traditional form of citizen-led initiatives in renewable energy has been cooperatives, universities have discarded this form due to its clear commercial connotations and profit-sharing implications. Cooperative at Aarhus University is an exception as it has been possible to form a cooperative without the university becoming a shareholding member in it. In other countries, the option of associations has been rejected due to their private nature, and the best legal formula observed is that of foundations. Considering the austerity rules governing public administrations in Spain and Portugal, including universities, both Technical University of Madrid and University of Évora rejected the possibility of forming a new foundation with mixed public–private capitals. Instead, they encouraged using the university's own resources to implement the idea. The study has researched the mechanisms that would allow the functioning of the energy community within the General Foundation of the Technical University of Madrid. However, it was ultimately rejected by regional authorities due to the foundation's 100% public nature, which requires 100% of its assets to be public, although legal teams hired by the researchers don't agree with such assumptions. The work provides details on critical points in the business models that can serve as inspiration when replicating the experience.

The study emphasizes the importance of acknowledging and understanding the barriers faced by the energy transition. The concept of energy communities supported by public administration has the potential to increase access to renewable energy for all and foster lifelong learning among citizens. However, the lack of clear regulations and the complex bureaucracy of public administration hinder the implementation of innovative energy transition initiatives. Is it more difficult to solve than technological limitations? Despite these challenges, this is an opportunity to unlock the potential of photovoltaic energy communities in the public sector, especially those that are not specifically addressed in the legal norms such as the universities. To facilitate the replication process across Europe and promote legislative changes, we need more individuals interested in analyzing how these energy communities can be implemented in their workplaces.

Despite all the hurdles, we have successfully established four distinct energy communities, each following different models. Although none of them qualify as true public–private partnerships, the Aarhus and Madrid models represent promising initiatives to kick-start the promotion of RECs around university campuses in Europe.

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Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Individual contributions included the following: **conceptualization**, A.B.C. and L.N.; **methodology**, A.B.C.; **research leaders**, A.B.C., L.N., Z.Z., M.V., M.B., L.F.; **surveys design,** A.B.C., Z.Z., M.V., C.S.-C.; **survey analysis**, C.S.-C.; **data curation and interpretation**, M.B., A.B.C.; **writing—original draft preparation**, A.B.C.; **writing—tables and graphs preparation**, C.S.-C.; **writing—review and editing**, A.B.C., Z.Z., M.V., M.B.; and **funding acquisition**, A.B.C. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The data that support the findings of this study are openly available in Zenodo at https://doi.org/10.5281/zenodo.7996966, reference number 7996966.

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citizen sciences, consumer (co-)ownerships, energy clusters, energy communities, energy transitions, European Union, universities

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