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Mapping of Energy Communities in Europe: Status Quo and Review of Existing Classifications

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Abstract: A lack of aggregate analysis concerning energy communities exists in the academic literature. The authors utilized a combination of literature reviews and desk research to fill this gap. The existing debate on the classification of energy communities was summarized and aligned. Discovered classifications were used to analyze the status quo of the sector. The authors found nearly 4000 energy communities with 900,000 members in the European Union. On average, there are 844 members per one energy community. Germany, the Netherlands, Denmark, and the United Kingdom are at the forefront of the movement. Different countries have different primary sources of renewable energy utilized by energy communities, and membership structures vary based on the energy source and corporate purpose of the energy community together with the sector's maturity in a certain country. Predominantly, hydro and biomass are used by energy communities in Alpine countries, solar energy is used in Germany, Spain, and France, wind in the Netherlands and Denmark, and different renewables in the United Kingdom. More members have joined the hydro, biomass, and wind communities than solar communities. Each country has national and regional associations of energy communities. In addition, intermediary actors, researchers, and consultancy agencies have shown a growing interest in the deployment of the movement. Achieving a conformity of business models Europe-wide would probably be impossible and pointless. Distinct geographical, institutional, and policy context-specific conditions stimulate diversity rather than conformity.

Keywords: energy communities; community energy; European Union; mapping; classification; status quo

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Citation: Koltunov, M.; Pezzutto, S.; Bisello, A.; Lettner, G.; Hiesl, A.; van Sark, W.; Louwen, A.; Wilczynski, E. Mapping of Energy Communities in Europe: Status Quo and Review of Existing Classifications. *Sustainability* **2023**, *15*, 8201. https://doi.org/10.3390/su15108201

Academic Editor: George Kyriakarakos

Received: 22 March 2023
Revised: 20 April 2023
Accepted: 10 May 2023
Published: 18 May 2023

1. Introduction

Within the energy transition, an innovative aspect of energy communities (ECs) is the promotion of a new actor on the stage of the energy transition, i.e., the prosumer [1]. Theoretically, every net meter connected to the grid, whether from an industry, a household, or a large building can play the role of a prosumer, by consuming or producing (renewable) energy during the day. However, key figures expected to enter this show are the household or the single citizen. By doing so, citizens may actively participate in the energy system and foster new networks of local relations by sharing their surplus energy. Through ECs, consumers will also find it easier to invest in renewable energy, and then consume, store, or sell the energy that they produce, and even, in the near future, provide flexible services [2]. Several studies (e.g., [3–5]) have already shown that, through these investments, households can save on electricity bills by installing photovoltaic (PV) systems, recovering the full cost of their investment in a short period, and the focus is shifting even more to innovative business models and enabling sharing technologies [4]. Energy communities already employ sustainable business models and must play an important role in the just transition. In most cases, returns from ECs remain in the locality, making them a unique opportunity for enhancing community welfare [5]. A French study conducted by Énergie Partagée [6] showed that for every EUR invested in a project, EUR 2.57 in value returns to the territory in 20 years. In addition to local economic benefits, community ownership and decision making in ECs significantly enhance local democracy and the acceptance of new green technologies [7–11]. Moreover, profits from energy savings in buildings can be redirected to additional actions such as shared e-mobility schemes. Community members are more likely than regional/national authorities to support such a local circuit of investment—improvement—investment because it goes against the traditional energy producers' lobby. Additionally, social aspects, such as having higher citizen support for projects promoted by community members themselves rather than by external institutions, mobilize citizen endeavours and local finance for the energy transition [12].

ECs make it easier for citizens, together with other actors, to team up and jointly invest in energy assets. This helps to contribute to a more decarbonized and flexible energy system since the communities can act as a single entity and access all suitable energy markets on a level playing field with other market actors. More specifically, ECs increase public acceptance of renewable energy projects and facilitate the mobilization of private capital investment in the clean energy transition [13,14]. At the same time, they have the potential to provide direct benefits to consumers by advancing energy efficiency, encouraging energy savings, and, thus, supporting lower energy bills [15]. Behaviorally informed citizen engagement strategies in ECs can help mobilize citizens to change their energy consumption habits by leveraging individual and social motivations to act pro-environmentally. ECs can, in this way, also tackle structural and behavioral drivers of energy poverty, supporting a just energy transition, including supporting the reduction of greenhouse gas emissions [16,17]. ECs also support lowered energy bills by generating energy and defining energy tariffs for their customers [18]. They can also incentivize consumers into adjusting their energy demands through demand-side management efforts, which can drastically improve the flexibility of the system. ECs can utilize storage technologies and demand–response strategies to enable both intraday and seasonal flexibility. At the intraday level, demand–response efforts can shift the energy load, for example, from peak load times to off-peak times [1]. This can result in avoided investments in additional power plants and reduce the overall stress on the power grid (and, as a result, avoid maintenance costs due to stressed grid infrastructure). In addition, demand–response can optimize local resources by matching local distributed generation to local consumption. For example, by matching energy demand with variable renewable energy supply, demand–response strategies can increase the supply of energy from renewable energy assets and further decarbonize the grid [19].

The new EU Renewable Energy Directive [20] helps with the administrative procedures and the new Electricity Directive [21] improves the market conditions. Estimates suggest that by 2030, ECs could own about 17% of installed wind capacity and 21% of solar. By 2050, almost half of EU households are expected to be producing renewable energy [18].

There is no consensus in the academic literature and public discourse on the precise definition of ECs despite more than a decade of research on them that started with the seminal paper of Walker and Devine-Wright in 2008 [22,23]. Therefore, our motivation is to provide an analysis based on collected data on the number and location of ECs in the EU, the main characteristics such as membership structure, energy technology utilized, and supportive ecosystem, and the main business models. Such an analysis would contribute to the clarity about the sector's current situation, thus highlighting its ongoing and future contribution to the energy transition. Our attempt to map and analyse movements in different countries aims to emphasize the importance of comparative analysis. While ECs have already also existed for a long time in several member states (MSs) in the form of historical cooperatives—e.g., Belgium, Denmark, Germany, Italy (especially in South Tyrol), the Netherlands, Spain (e.g., the historical cooperatives in the community of Valencia), Sweden, etc.—they are a novelty in others. With the Clean Energy Package (CEP) and related directives, the EU has, for the first time, introduced the concept of ECs in European legislation, notably Citizen energy communities (CECs) and renewable energy communities (RECs). In fact, the final CEP contains two definitions of energy community: the citizen energy community (CEC), which is contained in the Electricity Directive [21], and the renewable energy community (REC), which is contained in the Renewable Energy Directive [20]. They are similar but not completely equal. RECs can generally be seen as a subset of CECs. The defining difference concerns the fact that RECs are rooted in local communities, whereas this geographical scope does not exist for CECs.

ECs can take any form of legal entity—for instance that of a cooperative, a small–medium enterprise (SME), a partnership, a non-profit organization, etc. However, so far, the majority of ECs are in ranking: (i) cooperatives, (ii) community interest companies, or (iii) non-profit organizations (NPOs), partnerships, and private and public limited liability companies [24].

Against this background, a key element for success in the development of ECs is to support the exchange of best practices. The identification of best practices for citizen engagement in ECs as well as for market response must account for the large variability in contextual factors across member states (MSs), including sociocultural settings, and the supporting regulatory and policy framework. Different contexts will present different barriers to the engagement of citizens and different opportunities or threats to other market players; hence, the classification of ECs must account for such diversity [25].

In this study, the authors firstly provide a review of existing classifications and then find if and how such classifications align with the collected EU-wide data. In Table 1, authors compare their data and the Wierling et al. [26] database in terms of data collection scope and scale. Previously, energy communities were classified based on a certain characteristic or set of characteristics. Distinct approaches to classification were taken, precisely elaborating typologies, taxonomies, and ideal types. While each classification has a certain degree of detail as well as being scientifically rooted, neither of them provide a comprehensive picture of the overall phenomenon, which is renowned for its multifaceted nature. Furthermore, classifications based on characteristics such as: geographical context, membership size, enabling policy, and legal form were not clearly outlined in the academic literature although they are implicitly mentioned. By providing the lacking classifications, slightly modifying existent ones, and comparing the whole spectrum, the authors aim to summarize the existing scientific debate on the topic. Finally, the authors compare the main groups in terms of existing taxonomies, ideal types, and organizational forms as defined by the EU Directives in Table 2. By doing this, the authors aim to align the classifications to reveal if different studies describe similar organizational forms albeit using distinct wording. The authors leave all interested readers to choose a classification most appropriate to their own needs. Subsequent mapping and descriptive analysis of the aggregated data on energy communities uses terminology from the reviewed classifications. A lack of aggregated data is hindering a proper understanding of the development of ECs in the EU. A report on ECs by the Joint Research Centre of the European Commission [27] tells us that sufficient available information on the number and location of ECs is not available, as well as on their impact and potential for growth. Furthermore, the European Federation of Citizen Energy Cooperatives (REScoop.eu) emphasizes that there is a need for more comprehensive data collection on ECs to support their growth and development [28]. REScoop.eu estimates there are 1900 existing ECs [29], albeit stating that these estimates are only about half of the ECs active in Europe [30]. The lack of data presents a challenge for the European institutions and national, regional, and local authorities to effectively monitor and support EC initiatives. Thus, collecting and analyzing aggregated data are crucial for identifying and disseminating best practices and know-how for local authorities, citizens, and citizen organizations that wish to set up ECs, particularly but not exclusively in MSs with less developed EC traditions. Most of the previous studies performed analyses based on the data for separate case studies and in specific cases at a country level [31–39]. A number of exceptions providing information and analysis for several countries include Hewitt et al. [40] for eight countries and Wierling et al. [41] for four countries. Our research contributes to the analysis of the EU-wide movement rather than a separate country or a group of countries.

Table 1. Differences between databases.

Scope and Scale of the Data Collection	Authors' Data	Wierling et al. [26] Inventory
Sources of data collection	• Reports from third-party organizations/EC associations; • websites of EC associations; • public institutions' reports; • annual reports of initiatives; • handbooks; • working papers; • peer-reviewed journal articles; • book chapters; • websites of individual ECs.	• Registries operated by state agencies; • reports from third-party organizations/EC associations; • websites of EC associations; • public institutions' reports; • annual reports of initiatives; • handbooks; • working papers; • peer-reviewed journal articles; • book chapters; • websites of individual ECs; • direct interviews with members of ECs.
Nature of sources	Static	Static, dynamic
Membership	Collected	Collected
Annual energy generation/supply	Collected	Collected only for generation
Operational activities	Collected on the aggregate country-level (not including ECs that solely provide information and awareness services as their core activity, not including shared mobility projects)	Collected on the initiative level (including ECs that solely provide information and awareness services as their core activity, including shared mobility projects)
Number of employees	Not collected	Collected
Legal forms	Not collected	Collected
Financial assets	Not collected	Collected
Production unit capacity	Not collected	Collected

Table 2. Alignment of classifications of energy communities: ideal types, taxonomies, organizational forms defined by the EU.

Ideal Types from Reis et al. [42]	Groups/Clusters from Rossetto et al. [30]	Groups/Clusters from Braunholtz-Speight et al. [43]	Groups/Clusters from Moroni et al. [44]	Organizational Forms from the EU Directives [20,21]
Energy cooperatives	• Utility cooperatives; • Community energy producers; • Community energy retailers.	• Standalone renewables.	• Place-based; • Non-place-based.	• RECs (Community energy producers, place-based) • CECs (Utility cooperatives, community energy retailers, non-place based)
Community prosumerism	• Energy sharing communities; • Joint-purchase groups.	• On-site customer renewables.	• Place-based; • Multi-purpose.	• RECs • CECs (joint-purchased groups)

Table 2. *Cont.*

Ideal Types from Reis et al. [42]	Groups/Clusters from Rossetto et al. [30]	Groups/Clusters from Braunholtz-Speight et al. [43]	Groups/Clusters from Moroni et al. [44]	Organizational Forms from the EU Directives [20,21]
Local energy markets	• Energy sharing communities.	• On-site customer renewables.	• Place-based; • Multi-purpose.	• RECs
Community collective generation	• Energy sharing communities; • Community microgrids.	• On-site customer renewables.	• Place-based; • Multi-purpose.	• RECs
Third-party-sponsored communities	• Assistance providers.	• Demand-side activities.	• Place-based; • Single-purpose; • Multi-purpose.	• CECs
Community flexibility aggregation	• Community aggregators.	• Not found.	• Non-place-based; • Single-purpose.	• CECs
Community ESCO	• Assistance providers.	• On-site customer renewables; • Demand-side activities.	• Place-based; • Non-place-based; • Single-purpose; • Multi-purpose.	• CECs
E-mobility cooperatives	• Shared e-mobility providers.	• Not found.	• Non-place-based; • Single-purpose.	• CECs

This paper is organized as follows. In the Introduction we describe the aim of this study, the advantages that ECs could bring, the regulatory framework available at the EU level to support ECs, and the absence of the alignment of different classifications and reliable aggregate data on the general EC movement in the EU plus the UK; therewith, authors clarify the objective of their research. In Section 2, the authors outline the methods and data sources used in this research. In the Section 3, the authors present, analyze, and discuss the existent classifications of the sector: the typologies and taxonomies and current state of development of the sector, in terms of the cross-country distribution of ECs, membership base, main associations for supporting the sector, and energy produced by ECs where data are available. Finally, the authors discuss the factors behind the diversity of EC movement and the prospects in terms of policy and market dynamics. A Conclusion follows summarizing the obtained results and outlining a prospective research agenda.

2. Materials and Methods

Methods applied to the current work were the literature review and desk research. The former is applied to the analysis, while the latter is applied to both mapping and the analysis. The research began by elaborating on the EC classification and conducting a literature review of research studies that aimed to classify ECs, where proper classifications had already been designed. Literature review enabled us to analyse patterns after the data collection and properly name different groups of ECs. In addition, it helped with the clarification of reasons behind the sectors' diversity, which are discussed in Section 3. Except for the typologies, the ECs movement was classified in academic literature using taxonomies and "ideal types" [45]. Typologies are created to a greater extent by theorizing rather than by observation, whereas taxonomies, in contrast, are grounded in observation of the existing reality. According to Weber [37,38], business models, too, might be understood as "ideal types", for they seem to have the characteristics of both typologies and taxonomies: they are based on both theorizing and observation [46]. Ideal types can be viewed as a bridge between typology and taxonomy, sharing characteristics of both approaches. As a result, such typologies were outlined according to:

- Renewable energy (RE) technologies (own design mixed with [47]);
- The geographical context (own design);
- Membership size (own design);
- The corporate purpose [47];

- Initiating actor [33];
- Economic benefit for members (own design mixed with [39,40]);
- Enabling policy (own design);
- The legal organizational form (own design);
- Level of centralization of organizational structure [48].

Taxonomies clustering the existing ECs were organized by:

- Level of maturity of business model, by the main function performed [30];
- Type of energy activity undertaken, by organizational characteristics, by financing source, by revenue source [43];
- Physical location, by scope of corporate purpose [44].

Furthermore, eight ideal types (also called archetypes) were identified focusing on the value proposition of business models [42]. It is important to notice that taxonomies by Rossetto et al. [30] and Moroni et al. [44] partially carry features of the "ideal types" since these authors initially theorized on classification and, subsequently, found appropriate cases.

For the mapping exercise authors started with defining the concept of energy community. This outlined the scope for data collection. Each member state transposed the EU Directives [4,5] into national legislation resulting in diverse perspectives on organizational forms available for ECs. Since authors aimed at a comparative analysis of existent ECs and not their specific legal nature in different countries, they decided to search for organizations that correspond to the broader definitions outlined for the EU-wide level: RECs and CECs. This allowed a greater variety of organizational forms and business models to be mapped and analyzed.

Initially, the search string "energy communities in Country X" was applied to each EU member state in the Scopus database. Relevant publications were reviewed and the most updated information on the number, membership structure, and energy production of ECs was extracted. Authors found limited and obsolete statistics available in the academic literature. When a certain nationwide mapping was performed, its analysis related just to the separate countries or groups of them. Authors did not discover any EU-wide aggregate analysis. Country-scale mapping and subsequent analyses were performed for Spain [29,30], for Austria, Denmark, Germany, United Kingdom [41], for Germany [39], for Switzerland [25,49], for Sweden [37], for France [38], for Italy [27,48], for Belgium, France, Germany, Italy, Poland, Spain, Sweden, and the UK [40]. Moreover, authors found that the country-level data were outdated because most of the academic research had been conducted prior to the EU Directives' [50,51] transposition, which in turn drove the emergence of many new ECs. Therefore, for the second step, the same search criteria as was priorly applied to Scopus was applied to the Google search engine. Authors collected all available information from the web. It predominantly included grey literature reporting static information for a certain year, in particular:

- Reports from third-party organizations or EC associations [42,44,52–54];
- Websites of EC associations [22,54–59];
- Public institutions' reports [7];
- Annual reports of individual ECs;
- Handbooks [25,28];
- Working papers [34,60];
- Book chapters [5];
- Websites of individual ECs.

This allowed us to collect very recent advancements in the sector. The sources were intensively screened, and valid data were extracted. As a third step, authors searched the European Federation of Renewable Energy Cooperatives (REScoop.eu) website, where authors investigated one by one all its members through their respective websites and annual reports. A number of members of REScoop.eu are not the ECs themselves according to the EU definitions but rather the consulting firms or tertiary organizations or national/regional organizations promoting ECs. However, for several countries (i.e., Bulgaria, Luxembourg, Slovenia), the REScoop.eu website was the only available source of information. The process of data collection was not linear. Authors used the triangulation approach returning hence and forth to priorly examined resources to find a possible subsequent reference to additional resources. Importantly, the bibliography of the academic articles was investigated if the article itself did not contain the needed data. Our data were collected between 2019 and 2022, with a final screening in November 2022.

In January 2023, a database for the EU-wide ECs was released [26]. The database adheres to the rigorous FAIR (findability (F), accessibility (A), interoperability (I), and reusability (R)) guiding principles applied to the scientific databases [61,62]. It was compiled into the publicly accessible inventory. Table 1 represents differences between the data compiled by authors and the Wierling et al. [26] database relative to the scope and scale of the data collection.

The inventory composed by Wierling et al. [26] included not only static sources but also dynamic ones in their data collection, particularly registries operated by state agencies. This allowed them to report on initiatives that had terminated their existence as well as those currently existing. In addition, they conducted interviews with experts in the field and members of the ECs. Authors did not conduct the interviews, relying solely on desk research. Another important difference concerns the definition of search criteria for an energy community. While both criteria fall under the EU-recognized definitions of RECs and CECs, the Wierling et al. [26] inventory adopted a broader definition of ECs, aiming to be over-inclusive rather than under-inclusive. In contrast, our data collection adopted narrower criteria, including only ECs whose core activity is the generation and/or supply of energy, as well as those whose core activity is energy efficiency measures. Therefore, ECs that provide sharing mobility and/or information and awareness services as their core activity did not meet our search criteria. Due to these differences, Wierling et al.'s [26] inventory reports on over 10,000 ECs in the EU, while our report includes 3931 ECs. Importantly, the inventory of Wierling et al. [26] includes additional broad information on ECs, such as number of employees, legal forms, financial assets, and production unit capacity, which was not collected for our database. Thus, Wierling et al.'s [26] inventory enables greater possibility for a statistical analysis.

However, the strength of our data collection approach lies in its specialized focus on energy communities that are engaged in energy generation and/or supply, as well as those involved in energy efficiency measures, allowing for more targeted and specific analyses. Furthermore, our database exclusively includes currently active ECs, providing a more up-to-date snapshot of the current state and activities of these communities without the additional complexity of terminated ECs. This feature may be valuable to scholars, policymakers, and practitioners who are specifically interested in the more traditional activities of ECs. Given the great diversity in the EC movement, a narrower analysis can yield more specific research outcomes while keeping track of relevant developments.

After the data collection, authors designed Table A1 (see Appendix A), which includes both absolute numbers and descriptive statistics, such as the average number of members per EC and proportions relative to the total country population and total renewable energy generation. The generation and/or supply of energy was transformed into the descriptive indicator "Households consuming the ECs' generated/supplied renewable electricity". The table also indicates the reference year for which the static data were collected and list the national/regional federations of ECs. In Section 3, authors provide a comparative visualization of the descriptive statistics and subsequently examine patterns in the development of the EC sector.

3. Results and Discussion

3.1. Classifications

Several typologies [28,39,40] were derived from previous academic studies but were slightly modified to fully correspond to the results of our research. The rest of the typologies were designed by the authors. The taxonomies and ideal types were discovered using the literature review.

3.1.1. Typologies

According to the RE technology:

- Solar: Solar ECs utilize photovoltaic and solar thermal technologies;
- Wind: Wind ECs utilize wind turbine technology;
- Biomass/biogas heat/power. Biomass/biogas ECs utilize technologies allowing the production of heat or electricity from woodchip or from solid or liquid waste and husbandry leftovers such as manure if the biogas power plant is established. Such ECs include combined heat and power (CHP) technology to their generation portfolio [43];
- Hydro: Hydro ECs rely on hydropower technology and are usually represented by micro-hydro plants;
- E-mobility: For ECs, e-mobility means utilizing storage devices as a source of distributed energy. Usually, it is a side activity of the ECs, while the primary activity is the generation of electricity or heat. According to Herbes et al. [47], ECs could offer rental services for their customers with a small fleet of electric vehicles, establishing an infrastructure for electric bicycles, and car-sharing services. However, social enterprises whose sole purpose is shared e-mobility, as well as a source of charge for the batteries is not identified clearly, and the authors do not consider these to be ECs. As a result, the authors do not include them in Table A1.

A growing number of ECs in the EU, especially those established before the Directives [50,51], do not utilize one single RE technology but several simultaneously due to the maturity of their business model. During the research, the authors found only very limited empirical information about the renewable energy technologies utilized in the sector. Where country-wide cumulated data are available, they are reported using general terms such as “most”, “many”, “majority”, and “largest”. Precise numbers are not available for the EU as a whole, or for countries separately. However, during the review of the annual reports and websites of many ECs, the authors discovered that such data are available at the level of individual ECs.

According to the geographical context:

- Rural ECs: Cooperatives established in rural areas, of which members are usually rural citizens. Cooperatives are mostly based on the ”community of place” approach rather than the ”community of interest”. The authors also include smart villages in this category;
- Urban ECs: ECs established in urban areas, of which the members are usually urban citizens, frequently organized within the condominium of flats or compound of houses. Urban ECs have a great potential for environmental benefits. Emissions from buildings are the largest portion overall. Xiang et al. [8] pointed out that the end-user activities such as space heating, appliances, and others remained the major contributors to decreasing the energy intensity effect in the last decade. Therefore, ECs organized within a building condominium can be a very promising business model from the environmental perspective because an increase in the energy efficiency of buildings, both from the technical and behavioural aspects, is of clear economic interest for residents. This is a “community of place” approach. Moreover, urban ECs are frequently organized using a virtual business model where members own generation facilities in various regions of the country, and not exclusively in their proximity. Such ECs are based on the “community of interest” approach.

According to membership size:

- Very small EC: fewer than 50 members;
- Small EC: 50–200 members;
- Medium size EC: 200–500 members;
- Large EC: 500–2000 members;

- Very Large EC: more than 2000 members.

According to the corporate purpose, derived from Herbes et al. [47]:

- Generation of energy;
- Operating grid: distribution and/or transmission (rarer). Frequently, such ECs own biogas installations and provide balancing services;
- Retail: Selling renewable energy to customers with certified pro-environmental effects;
- Consumption-related services (consulting services, demand-side management, distributed storage, operating charging points for electric vehicles, energy efficiency models, peer-to-peer trading, microgrids).

According to the initiating actor, derived from De Vidovich et al. [33]:

- Public lead model: These ECs are initiated by municipalities or other public governing bodies, usually local;
- Pluralist model: These are organized by the ecopreneurs, NGOs, local SMEs, and other stakeholders. The main features are the organization "from grassroots" as well as the fact that several local actors join the efforts to establish an EC;
- Community energy builders: Usually organized by a well-established intermediary organization, big cooperative, a research or consultancy agency specifically active in the field, or a national or regional association of ECs. The main feature is that such an entity establishes many ECs of a certain type, duplicating the business model with only slight changes.

The data on geographical context, membership, corporate purpose, and initiating actor are available in the academic and grey literature for France, Spain, Germany, the UK, the Netherlands, Belgium, and Italy. However, it is labelled very differently, which further complicates its extraction and accumulation. Furthermore, most of the data are outdated, at least by several years. Data about the initiating actor are harder to collect. Information to build the classification according to the initiating actor either is not available or reported anecdotally, without quantitative information. Prior research activities should be carried out.

According to the economic benefits for members:

- Lower price for energy: The EC works as a utility selling energy to consumers directly and thus receiving direct payments from them. Usually, the consumers who are simultaneously members have lower bills. A lower cost for energy is therefore a main economic trigger to participate. A difference in price with other retailers forms usually due to the special policy preference or particularly organized business model;
- Dividend pay-out: ECs in which members invest in their own RE generation facilities and receive the revenues as shareholders. It allows for higher incomes, albeit demanding closer management [50];
- Participation in energy savings: Consulting services to municipalities and households (HHs) on energy efficiency topics could be an additional revenue stream;
- Contracting: ECs as well as using other revenues in their business model, also use contracting;
- Leasing: When the revenues come from the leasing fee. Herbes et al. [47] states that revenue would be generated as part of the rental fees for the equipment to the consumer.

According to the enabling policy:

- Feed-in-premia (FIP): ECs relying on the selling of electricity to the grid and the premium tariff provided by the governments to stimulate the deployment of renewable energy;
- Quota obligations: It is an obligation of utility companies/energy suppliers/big energy producers to buy a certain share of the renewable energy (RE) imposed by governments. Quota obligations are created for the dissemination of renewable energy sources (RES). Many ECs in the EU benefit from such a policy;

- RE certificates: RE certificates are the documents that guarantee that a certain amount of RE was produced. Later they are sold to the other energy market players. This is a tool that in most cases is accompanied by the quota obligations. However, the difference is that a separate market is created to trade RE certificates;
- Preferential taxation: For ECs there exist various forms of preferential taxation. It can be in a form of a tax deduction or complete exemption from certain taxes, which otherwise are imposed on market players;
- Investment support: Usually occurs in the form of public grants or preferential loans to cover the capital costs, which make this tool different in nature from the grants or preferential loans subsidizing operational activities.

Data on economic benefit for members are available on the websites of ECs and in annual reports. However, neither national nor regional associations or federations have yet accumulated it. Data on enabling policy are available in the academic literature for all EU countries where the phenomenon exists, except for Finland, Poland, Slovenia, or Romania.

According to the legal form data apply to:

- Cooperatives;
- Community interest companies;
- Non-profit organizations (NPOs);
- Partnerships;
- Limited liability companies.

Data for the legal form can be found in public online databases as well as being collected from the ECs' open sources such as websites and annual reports.

3.1.2. Taxonomies

The taxonomy proposed by Rossetto et al. [30] is similar to the typology of the corporate purpose [47] but encompasses more organizational forms. The authors offer a taxonomy structured by the main functions performed on one side, and by the level of maturity of the business model on the other side. Taxonomy contains such groups of ECs: joint purchasing groups, assistance providers, community energy producers, community energy retailers, utility cooperatives, energy sharing communities, shared electric mobility providers, community aggregators, and community microgrids. Joint-purchasing groups are citizens who by unifying within an EC can better bargain with technology vendors or energy retailers. Assistance providers assist members of the community in energy efficiency measures by providing technical support, and facilitating access to finance and awareness campaigns. Groups with a primary purpose to tackle energy poverty belong to this category. The "Community energy producers" collectively purchase generation facilities benefiting from selling energy to the grid. The "Community energy retailers" exclusively sell renewable energy to its members, frequently offering lower prices. In specific cases, ECs under this category own the generation facility too. The category of "Utility cooperatives" mostly includes historical cooperatives in mountainous or remote rural areas that invested in the distribution system infrastructure to connect individual consumers with its own generation facilities or transmission network. Within the "Energy sharing" category, the authors distinguish collective self-consumption and peer-to-peer trading. According to both types, prosumers purchase PV plants and storage devices to cover their energy consumption. However, a difference is that according to collective self-consumption schemes, the renewable asset is owned collectively, while individual members continue to have their own energy providers that take care of their residual demand when the community asset does not cover the energy demand. In contrast, members of peer-to-peer (P2P) trading schemes individually own the generating and storing assets that are connected to a digital platform. Individually generated electricity is traded within the community in a way that reflects peers' personal preferences (e.g., price, origin, destination of the energy). Thus, a key task for the P2P scheme is the provision of a digital infrastructure for trading. "Shared e-mobility providers" purchase a fleet of electric vehicles and make them available to their members. The last two categories "Community aggregators" and "Community microgrids" are described by the authors as the most innovative. Both manage and combine the load of their members. While community aggregators virtually connect consumers, prosumers, and collective generation assets, the main feature of microgrids is a physically connected infrastructure.

The taxonomy offered by Braunholtz-Speight et al. [43] is empirically grounded. The researchers used a collected dataset on the ECs in the UK. The research itself contains two parts: the construction and analysis of the taxonomy, and the performance and financial analysis. Taxonomy was constructed using cluster analysis, which was run in two sets. In the first run, only "energy activity" variables were used. This produced three clusters: standalone renewables, on-site customer renewables, and demand-side activities. "Standalone renewables" include ground-mounted wind, hydro, solar, and biomass projects. The "On-site customer renewables" cluster almost entirely consists of rooftop solar photovoltaic projects, while the "demand-side activities" cluster consists of a mixture of energy efficiency advice projects with renewable energy generation for their own use. In the second run of the cluster analysis, the researchers also utilized variables on organizational characteristics, financing sources, revenue sources, and location. Three broad clusters were subdivided into 12 smaller ones. "Standalone renewables" had two subclusters: multi-financed hydro and wind, and large wind selling to the grid. "On-site customer renewables" had seven subclusters: medium-scale generation with mixed financing, small–medium solar rooftop, multi-site solar on public sector roofs, professionalized solar rooftop co-ops, small multi-project generation for third sector groups, small solar rooftop, and smaller-scale multi-project co-ops. The "Demand-side activities" cluster had two subclusters: demand-side services and energy as a side line. An additional subcluster was produced after the second run that did not belong to any of three main clusters, multi-tech generation including partnerships. The authors discuss, in detail, the features of each cluster and subcluster.

The taxonomy of Moroni et al. [44] categorizes ECs by physical location and by the scope of the corporate purpose. The first category consists of two groups: place-based and non-place-based communities. This explains the correspondence between the community and a specific area [44]. The second category also reveals two groups: single-purpose and multi-purpose. ECs that are organized solely for energy purposes are labelled as single-purpose, whereas those with a range of objectives including goals encompassing the shared management of energy systems are labelled as multi-purpose.

3.1.3. Ideal Types (Archetypes)

The research by Reis et al. [42] identified eight community business model archetypes. For this purpose, data were collected by the review of case studies from the academic literature, and the Business Model Canvas and Lean Canvas frameworks were used as the main methods. The following archetypes were identified: energy cooperatives, community prosumerism, local energy markets, community collective generation, third-party-sponsored communities, community flexibility aggregation, community ESCO (energy service company), and e-mobility cooperatives.

3.1.4. Organizational Forms Defined by EU Directives

The main differences between RECs and CECs relate to the activities and eligibility criteria:

- Activities: CECs participate across the electricity sector, while RECs focus only on renewable energy. Most importantly, RECs have a narrower geographical scope of activities;
- Eligibility to participate: as well as citizens and small end-users, entities of any size can participate in a CEC, while RECs limit participation to micro-, small-, and medium-sized enterprises (SMEs);
- Effective control: CECs need to be effectively controlled by natural persons, local authorities, or micro and small enterprises, while RECs must be effectively controlled by members that are located in proximity to the community's projects, without any size reference;

- Autonomy: RECs have to be autonomous (and hence more democratic) in their internal decision making, while this is not mentioned for CECs [12,63].

In Table 2, the authors align the ideal types as defined by Reis et al. [42] with groups/clusters represented by taxonomies [24,45,64], and organizational forms defined by the RED-II and IEM Directives [20,21].

3.1.5. Reflection on Results

Classification and analysis of the organizational and legal forms are also essential because they enable a subsequent analysis of management issues and a comparison between countries. The transaction cost theory provides a good argument as to why this is worth investigating further. As Bonus [10] pointed out for cooperatives, "within the typology of transaction costs and governance structures, cooperatives are classified as hybrids within the spectrum of coordination mechanisms, ranging from market to hierarchical organization. The cooperative association possesses features that provide benefits in terms of integrating transactions into a collective organization, while allowing independence of other operational aspects." If cooperatives are not fully market-based organizations and possess features of hierarchical organizations, since they can pool their qualifications and resources (e.g., for joint-purchase bargaining and technical qualification) and the use of the market is more limited, then what might be the relationship of other organizational and legal forms with energy markets? Here, a particular interest concerns emerging business models such as community aggregators and peer-to-peer trading. The trading digital platform represents a fundamental "matching loop" as it reduces the otherwise exorbitant transaction costs for the peers [11]. Which organizational form would adjust better to the existing energy markets and be deployed faster without harming other players? Research studies that allow us to answer such complex questions have only recently been performed due to the publishing of country-based databases (e.g., [43]) and the EU-wide database [26]. Hence, the authors anticipate an agenda for energy community research that will expand our understanding of the role of ECs in the greener energy markets.

3.2. Mapping

The movement of ECs in the EU is not homogenous. Countries such as Germany, the Netherlands, Denmark, and the United Kingdom are leading the process, whereas in countries such as Italy or Spain the processes involved in the emergence of new ECs has started; however, their number is still small. The majority of ECs in Italy and Spain are represented by the historical cooperatives, which date back to the 20th century and supply rural mountainous valleys with electricity and heat. In other countries, such as Poland, Slovenia, and Bulgaria, the authors found ECs in only exceptional cases. These developments are depicted in Figures 1 and 2.

As can be seen in Figures 1 and 2, Germany has the highest number of ECs relative to other countries, followed by the Netherlands and Denmark. In Germany, most of the ECs generate solar energy, while in the Netherlands and Denmark, ECs generate electricity from wind and heat from biomass. The factor behind the Danish leadership is the particularly large number of ECs that utilize biomass, i.e., 341 of 527 total ECs. This is a direct result of the prohibition by law of district heating systems from making profit [65]. In the UK, ECs that generate solar, hydro, and wind energy dominate. The British EC sector is not only one of the most developed in terms of quantity but also in terms of the ecosystem, with diverse business models and many stakeholders engaged in the sector, including industry, local governments, and NGOs.

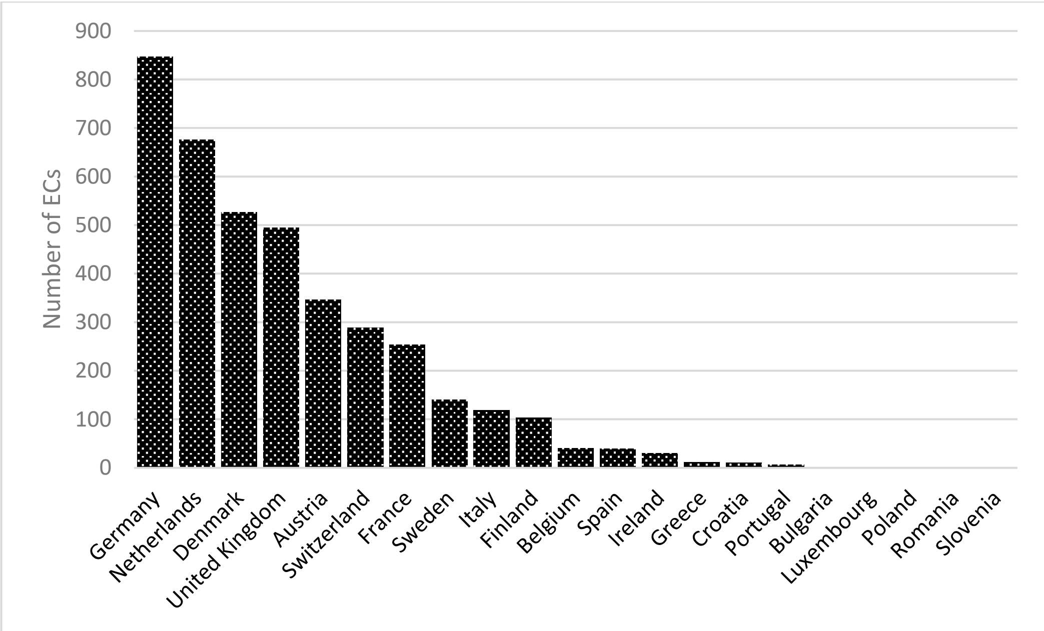

Figure 1. Deployment of energy communities in the European Union (Source: Table A1 in Appendix A).

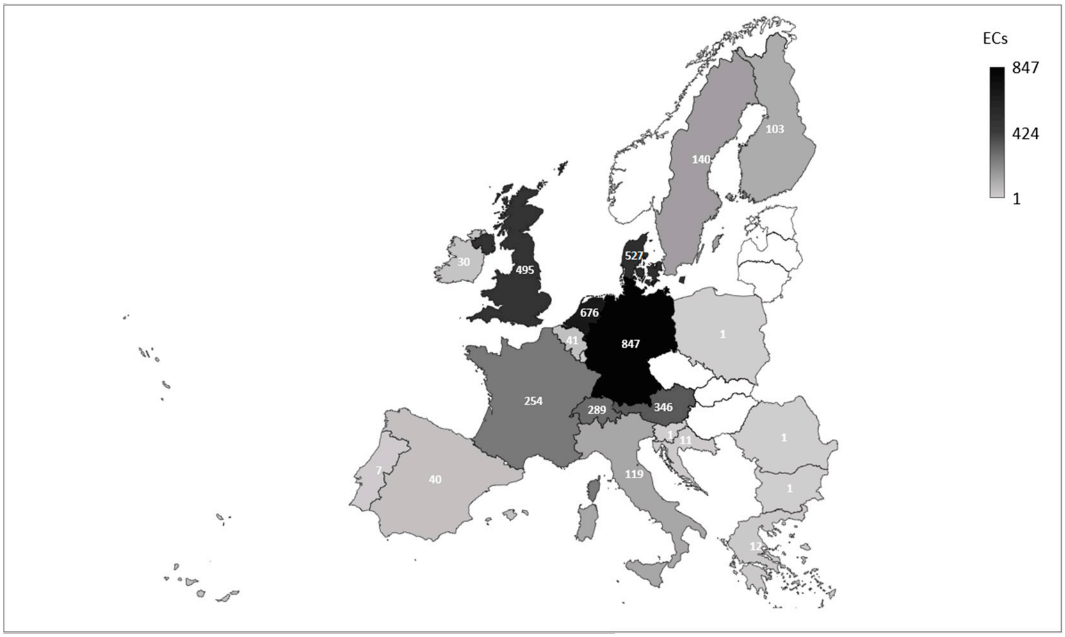

Figure 2. Map of energy communities in the European Union (Source: Table A1 in Appendix A).

In Switzerland, most of the ECs are district heating biomass cooperatives, which usually involve a greater number of citizens than solar or wind cooperatives. In Figure 3, the bubble size represents the number of ECs, and we observe that France has a similar number of ECs to Switzerland. However, the latter have twice as many members in their ECs compared to the former. The same situation occurs when comparing Switzerland to the Netherlands, which is one of the leaders in the number of EC initiatives. The average members per one EC is higher for Switzerland than for France and the Netherlands, which can be observed on the horizontal axes. Similarly, the majority of 349 ECs in Austria are district heating biomass cooperatives. Although data on membership are not available for Austria, the authors suppose that it follows the same pattern as Switzerland.

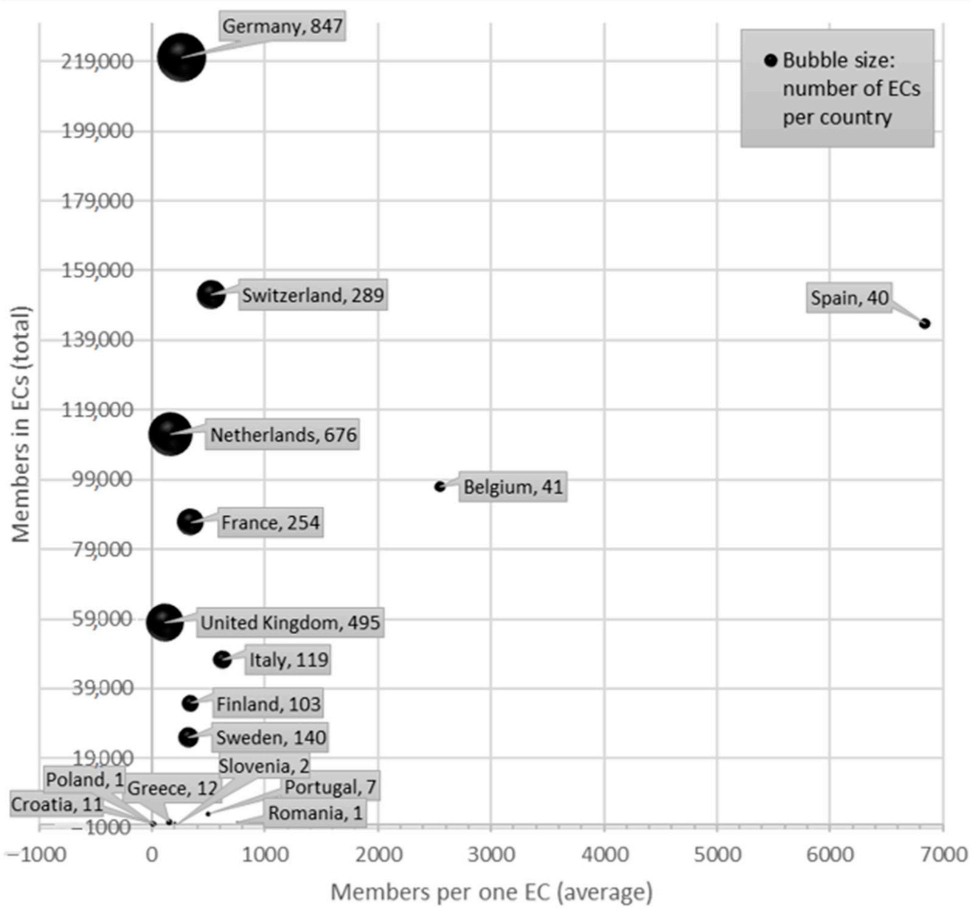

Figure 3. Membership and the average size with respect to the number of energy communities in the European Union countries (Source: Table A1 in Appendix A).

Figure 3 shows the average number of members per EC in EU countries. Spain and Belgium are outliers with average membership numbers of 6841 and 2552, respectively. This difference from other countries is due to the presence of powerful retail ECs. In Spain, for instance, 20 out of 40 ECs sell electricity to consumers as their main business activity, with Som Energia being the most prominent with 83,039 members. In Belgium, the Ecopower energy cooperative consists of 64,114 members. Retail cooperatives' members are simultaneously their customers, although retail ECs can supply energy to non-member consumers. These types of ECs contract renewable energy producers predominantly to supply customers with clean energy. Such enterprises usually aim for social good, leading to decreased energy prices and sustainable energy provision. Another cluster of countries with an average number of members lower than Spain and Belgium, but higher than the rest of the countries, includes Italy, Portugal, Switzerland, and Finland, with average numbers of 622, 500, 526, and 338, respectively. In Italy, a retail EC called E'Nostra comprises 10,702 members. In Portugal, a big retail EC called Coopernico exists with 2531 members. In contrast, Switzerland and Finland have a high average number of members due to district heating biomass/biogas cooperatives.

Figure 4 illustrates that, although Germany is a leading country in terms of the number of ECs in the EU, less densely populated countries, such as Switzerland, Belgium, the Netherlands, and Finland, exhibit higher densities of citizens per energy cooperative member. The density ranges from 57 in Switzerland to 159 in Finland, while Germany has a comparatively modest density of 378. Among these countries, the Netherlands and Belgium have the highest number of wind cooperatives, while Switzerland and Finland have a significant number of district heating biomass/biogas cooperatives.

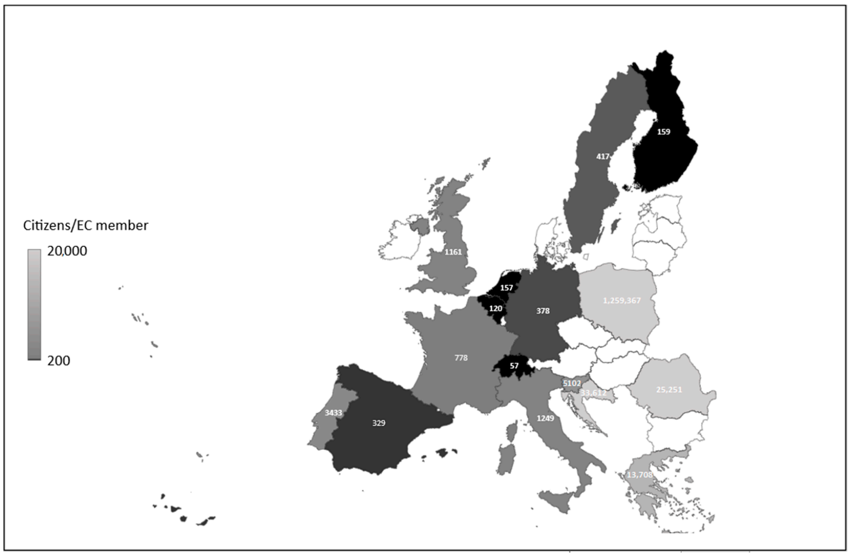

Figure 4. Population involved in energy communities, citizens per one member. (Source: Table A1 in Appendix A).

Figure 5 depicts the membership and consumption proportions only for EU states where energy generation data are available. Countries with higher proportions have lower bars, and vice versa. Belgium, Germany, and the Netherlands have the highest membership and consumption proportions among the sample countries, indicating their leadership and that their ECs generate and supply renewable energy equivalent to their members' consumption. Slight variations in proportions are observed for the UK, France, Italy, and Portugal, suggesting that a single EC member in these countries provides (either through participation in clean energy generation or by selling) considerably more energy to citizens than it needs for his own consumption. This can be visualized by the difference between bars of the respective country. In Greece and Romania, a significant deviation between membership and consumption proportions exists because only a few ECs have been established, despite managing large renewable power projects.

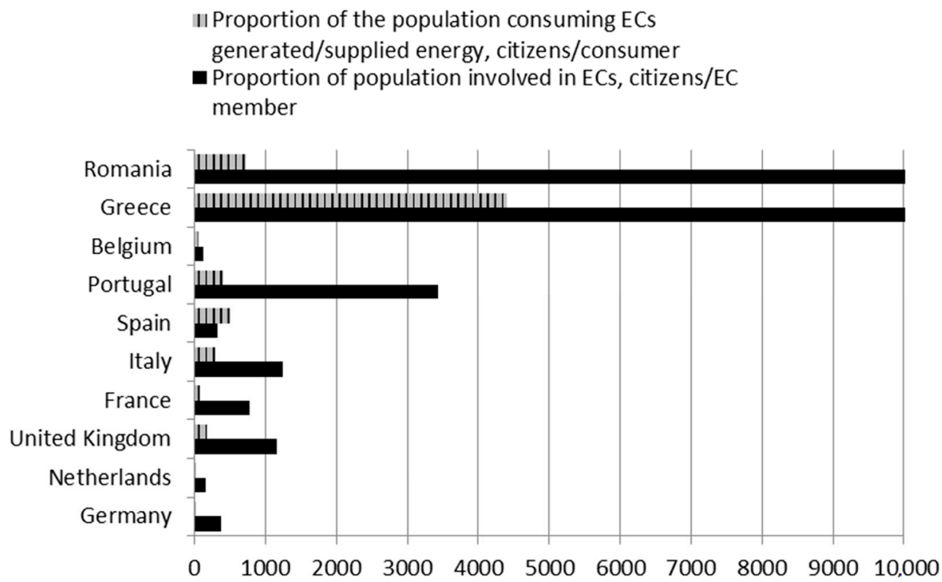

Figure 5. Comparison of citizens participating in energy communities and consuming its energy (Source: Table A1 in Appendix A).

The European Federation of Energy Cooperatives (REScoop.eu) is the umbrella organization that represents ECs throughout Europe. It comprises individual ECs, national/regional federations, and even associate members that are not ECs themselves. However, our data collection revealed that many ECs, such as historical hydro cooperatives and district heating cooperatives in Alpine countries and new ECs that emerged after 2019, are not members of REScoop.eu.

In several countries, intermediary organizations assist ECs in their operation and lobbying activities. These organizations are mostly represented by national/regional federations, such as REScoop Flanders and Wallonia in Belgium, Energie Samen in the Netherlands, Community Energy England/Scotland/Wales in the UK, and DGRV in Germany. In addition, sector builders, such as Énergie Partagée and Enercoop in France, E'Nostra and WeForGreen Sharing in Italy, and Energy4All in the UK, established new ECs as their spin-offs. These sector builders have an organizational nature of the "cooperative of cooperatives". Another type of sector builder consists of research and consultancy organizations, such as the University of Ljubljana's Energy Policy Laboratory in Slovenia and the Energy Center Lab of the Polytechnic University of Turin in Italy, which has started to be particularly active since the enforcement of the EU Directives [50,51] in 2020–2022. Another type of sector builder was launched in Austria. It is a public institution for the deployment of ECs at a national scale, the Austrian Coordination Office for Energy Communities. The last two types of sector builders concentrate on the development of new ECs rather than supporting the well-established ones. They bridge between different actors within a variety of contexts to establish innovative business models. The most prominent intermediaries are listed in Table A1.

3.3. Impact of EU Directives

New ECs started to appear after the transposition of the EU Directives [50,51] to national legislations, which happened between 2020 and 2022. Their rapid emergence was observed in Italy and Spain because the national legislations in these countries allowed new actors, who were not previously involved, to step into the energy market. As a result, the organization of these new ECs is different from traditional energy cooperatives. For instance, municipalities and housing associations could not only become members of ECs but even initiate an EC themselves [28,48,66]. In Italy, 26 such new ECs have emerged since 2020. On the opposite side of the EC movement, the authors found historical ECs that usually appeared in remote villages in mountains, typically including all local citizens as members [5]. A number of them (i.e., ECs represented by the SEV association in Italy) date back more than a century. They started to generate renewable hydropower and provide it to locals [67]. At the beginning of the 21st century, their business models were expanded to the provision of district heating from biomass/biogas. Such cooperatives are found in Alpine countries such as Italy, Austria, and Switzerland, but not exclusively. For example, historical cooperatives that supply a village or valley with electricity operate in Spain, and they are united under the umbrella of the Federation of Electric Cooperatives of the Community of Valencia. To fully realize their potential, ECs must develop in terms of their diversity of organizational forms that was enabled by the EU Directives [50,51] in 2018 and 2019. Classification according to legal organizational form and initiating actor would not only systematize the sector but also provide insights. For example, the authors found that Italy transposed EU Directives that allowed many new players in the market, such as municipalities, small–medium enterprises (SMEs), non-governmental organizations (NGOs), research bodies, social housing associations, and religious organizations, to be organized in an EC under any legal form. Before this, only 77 ECs existed in Italy, most of which were energy cooperatives in Alpine rural areas [67]. In 2022, 119 ECs existed, a 35% growth due to newly established ECs of different legal forms from the cooperative. Germany, on the other hand, had 862 ECs [68] before the EU Directives and 847 ECs in 2022, so the number has almost not changed. Directives were transposed into German law, implying that cooperatives are the main legal form intended for ECs. Other legal entities in the German legislation were not specified [69]. Moreover, in Germany, fewer new actors could be involved in ECs such as SMEs, municipalities, and NGOs. Monetary incentives, however, were promised in both countries. Thus, the difference in recent dynamics for Italy and Germany occurs due to the distinct number of actors as well as legal entities. While Italian legislation has enabled new actors to step into the sector, it has not recognized utility cooperatives (historical cooperatives) as a form of ECs. In contrast, our inclusion criteria were based on the definition provided by the EU Directives. That is why authors mapped historical cooperatives to the ECs.

3.4. Economics

According to Elinor Ostrom [70], there are three economic factors that enable communities to address modern challenges more effectively. Firstly, they can address local externalities more efficiently. Secondly, they can respond to preferences for locally differentiated goods. Thirdly, they can group together to reach an efficient scale of operation in production or trade [71]. We should not forget about the vast social benefits of decreasing energy poverty and increasing energy democracy, which could consequently contribute to economic outcomes too. Therefore, there exists a "non-efficient quantity" of small and distributed capacity installed by ECs. If so, governments need to subsidize it until the sector reaches maturity. Studies have shown that without governmental support, today's ECs could barely survive [45,72]. When such support is provided, the ECs' number and sizes will grow. When this sector attains maturity and an efficient market-justified number of ECs is reached, the growth will cease and thus support can be gradually eliminated. ECs that succeed and stay in the market due to the evolution of their business models and higher productivity will be able to compete with larger players from then on. New efficient prices, which consider the environmental and social aspects of energy, will enable such a scenario to happen. It will be less costly to build and operate small generation facilities. Finally, the unproductive ECs will vanish. Nonetheless, until the market fully embraces ECs, supportive policy tools are crucial.

It is not only policy tools but also the role of investors who are sensitive to ethical finance that can contribute to the deployment of ECs, given the general increase in interest in environmental, social, and governance (ESG) ratings of the portfolios and investment options [73]. Socially responsible investing has not only demonstrated high social and environmental cruciality, but it has also become more profitable than investing with the sole purpose of maximizing profits. The recent Corporate Sustainability Reporting Directive [74] obliges small and medium-sized enterprises (SMEs) to report on their ESG performance from 2026. As the authors have discussed, ECs are organized in various legal forms in different member states. Those that choose to be an entity corresponding to the SME type will be obliged to report on their ESG. Whether this will increase transaction costs for newly established ECs or, conversely, bring positive outcomes such as additional funding, we do not know yet. However, the possibility of being registered under different legal umbrellas should add to the survival chances and development of the sector. ECs that find it burdensome to report on ESG could simply be registered as entities that are not required to disclose those numbers. ECs should be allowed to evolve by testing various business models [5]. This experimentation will permit ecosystem heterogeneity (with multiple key actors) that, in turn, will speed up the evolution of ECs' business models and consequently the deployment of renewable energy. ECs should utilize their uniqueness, which lies in their strong direction towards stakeholders such as the local community in general or the environment, rather than only shareholders. Business model adaptation by other market players, as suggested in the studies of business model archetypes and taxonomies [24,47], can accelerate the process. For instance, DSOs see the potential in ECs to be aligned with their own business models, which was described in Del Pizzo et al. [75]. In the majority of member states, a separate small–medium company can also be one of the members of an EC, although aligning with the cooperative principles. Participation in the EC and a possible installation of generation facilities within the commercial building of a company, although owned by an EC, can add more sustainability value to the portfolio of such an SME member and help to showcase innovative ways to decarbonize commercial building stock. As Minda Ma et al. [76] argue, stimulating policies and new market financial mechanisms are important to accelerate decarbonization of the commercial buildings. As we can see, urban ECs can evolve in multiple directions, which could engage not only residential but also commercial buildings. For instance, community microgrids, community aggregators, assistance providers, demand-side activities, and peer-to-peer schemes could become suitable models for businesses willing to take a stake in an emerging sector. The authors do not yet know the future dynamics of the energy market and its interrelation with ECs, but we are convinced of the importance of ECs developing in various organizational forms that allow for ecosystem heterogeneity and fluidity. Koltunov et al. [5] argue that, when comparing the French and Italian EC movements before the implementation of the EU Directives, the French movement was more advanced than the Italian one because it was supported by a more developed ecosystem for ECs. Therefore, when SMEs in the EU are finally required to report on ESG, ECs that choose this legal form should only benefit. Markets may be more important than policies in driving the sector if the profitability assessments of new projects align closely with the sustainable and circular economy paradigms, thereby fostering an impact-investing approach [5].

4. Conclusions

This paper described the process and results of analysing today's activities revolving around energy communities. Key findings of the study are:

1. The authors found that there are nearly 4000 (3931) energy communities in the European Union and the United Kingdom today. The emergence of energy communities started well before EU Directives were put in place, with Germany, Netherlands, Denmark, and the United Kingdom being leaders in the movement.
2. The concept of community energy originated in the British academic circles [8,76,77] to emphasize the diverse nature of the phenomenon. However, in countries with stronger cooperative traditions, they were referred to as energy cooperatives. For example, in 2022, the authors found that there are 847 energy cooperatives operating in Germany and over 500 (527) in Denmark.
3. Different primary renewable energy sources are utilized by energy communities in different countries. In Alpine range countries such as Austria, Switzerland, and Italy, hydropower plants and biomass district heating plants are built extensively by energy communities in rural areas. Biomass district heating energy cooperatives dominate in Sweden and Finland. Conversely, the majority of energy communities in Germany, Spain, and France generate solar energy. In the Netherlands and Denmark, a great number of wind energy communities are operative.
4. An important insight from our work is that the membership structure of energy communities in different countries is related to the energy source used and the corporate purpose of the energy community. More members participate in biomass/biogas district heating communities and wind communities, which require bigger investments. Retail energy communities that mostly sell energy produced by others also tend to have many more members than purely energy generation communities. The largest retail energy community in the European Union, Som Energia, includes about 83,000 members who are simultaneously consumers and have preferential prices and a guarantee of the renewable origin of the supplied electricity.
5. Another insight from our analysis is that regional and national associations exist in each country where a significant number of energy communities are present. In addition, intermediary actors, research, and consultancy agencies show growing interest in the deployment of the movement. In France, Belgium, the Netherlands, and the United Kingdom, an ecosystem for energy communities can be a benchmark for other member states. The interrelation of energy communities with markets and how to properly support them without harming other players, as well as final consumers, poses a crucial

issue for further research on the topic. This issue is posed by Jean-Michel Glachant [71] in the preface of the book on energy communities: "How can energy communities become promising models for different actors along the value chain?"

6. Our work demonstrated that more clarity in the field of energy communities in Europe concerning their location, utilized technology, size, corporate purpose, legal form, organizational form, benefits for members, initiating actor, enabling policy tools, and more are needed. This will allow for the benchmarking of best practices across different member states, not only for the type of business models but also for sector builders, intermediary practices, and supportive policy mechanisms. However, achieving conformity of business models Europe-wide would probably be impossible and pointless. Distinct geographical, institutional, and policy context-specific conditions stimulate diversity rather than conformity.

With the publishing of an EU-wide inventory [26], the scope of energy community research is expected to grow. An interesting direction of research is the interrelation of new business models with other market players. In academia, energy communities were previously investigated mostly by sociologists, economic geographers, urban planners, and management scholars. The authors expect growing interest in the topic from energy economists.

Author Contributions: Conceptualization, M.K. and S.P.; data curation, M.K. and S.P.; writing—original draft preparation, M.K. and S.P.; writing—review and editing, M.K., S.P., W.v.S., A.B. and A.L.; supervision, S.P.; validation, A.B., W.v.S., G.L., A.H., A.L. and E.W. All authors have read and agreed to the published version of the manuscript.

Funding: The authors thank the Department of Innovation and Research of the Autonomous Province of Bozen/Bolzano for covering the Open Access publication costs.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Data available on request due to privacy restrictions.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Deployment of energy communities in the European Union.

Country	Number	Members of ECs	Members Per One EC (Mean)	Approximate HHs Number [1] Consuming Electricity Generated/Supplied [2] by ECs	Country Total Population	Proportion of Population Per One EC	Proportion of Population Involved in ECs, Citizens/EC Member	Proportion of the Population Consuming ECs Produced Energy [3], Citizens/Consumer	National/Regional Federation of ECs or Sector-Builders	Status Year	Source
Austria	346 [4]	-	-	-	8,956,290	25,885	-	-	Österreichischen Koordinationsstelle für Energiegemeinschaften	2018	[7,41]
Belgium	41	96,966 [5]	2552 [6]	96,102	11,587,880	282,631	120	52	REScoop. Vlaanderen, REScoop. Wallonie	2021	[60,61], websites and annual reports of individual ECs
Bulgaria	1	-	-	-	6,899,130	6,899,130	-	-	-	2022	[29], websites of individual ECs
Croatia	11	116	11	-	3,899,000	354,455	33,612	-	-	2021	[29,54]
Denmark	527 [7]	-	-	-	5,856,730	11,113		-	-	2018	[41]
Finland	103	34,775	338	-	5,541,700	53,803	159	-	-	2015	[54]
France	254 [8]	86,720	341	404,746 [9]	67,499,340	265,745	778	73	Énergie Partagée, Enercoop, Centrales Villageoises	2022	[58,78,79]
Germany	847	220,000	260	2,378,378	83,129,290	98,146	378	15	DGRV	2020	[55], energy consumption—own calculation based on [55]
Greece	12	778 [10]	156	1052	10,664,570	888,714	13,708	4409	ElectraEn	2022	[29], websites of individual ECs
Ireland	30	-	-	-	5,028,230	167,608	-	-	Nationwide Community Energy Ireland CLG, Energy Cooperatives Ireland, Sustainable Energy Authority of Ireland	2021	[59]

Table A1. *Cont.*

Country	Number	Members of ECs	Members Per One EC (Mean)	Approximate HHs Number [1] Consuming Electricity Generated/Supplied [2] by ECs	Country Total Population	Proportion of Population Per One EC	Proportion of Population Involved in ECs, Citizens/EC Member	Proportion of the Population Consuming ECs Produced Energy [3], Citizens/Consumer	National/Regional Federation of ECs or Sector-Builders	Status Year	Source
Italy	119 [11]	47,309 [12]	622	88,272 [13]	59,066,220	496,355	1249	291	SEV (only for South Tyrol region), WeForGreen Sharing, Energy Center of Politecnico Torino, Energy4.com, Fratello Sole	2021	[5,33,57] websites and annual reports of individual ECs
Luxembourg	1	-	-	259	639,070	639,070	-	1074	-	2022	[29], websites of individual ECs
Netherlands	676	112,000	166	380,000	17,533,400	25,937	157	20	Energie Samen	2021	[53,62]
Poland	1	30	30	-	37,781,020	37,781,020	1,259,367	-	-	2022	[80]
Portugal	7	3000	500	11,174	10,299,420	1,471,346	3433	401	-	2018	[29], websites of individual ECs
Romania	1	757	757	11,351	19,115,150	19,115,150	25,251	732	-	2021	Websites of individual ECs
Slovenia	2	413	207	-	2,107,010	1,053,505	5102	-	University of Ljubljana Energy Policy laboratory	2022	[29], websites of individual ECs
Spain	40	143,668	6841	40,239	47,329,690	1,183,242	329	511	Red de Comunidades Energeticas S.coop, Union Renovables, Federation of Electric Cooperatives of Community of Valencia, Sapiens Energia	2021	[29,34,35], websites and annual reports of individual ECs
Sweden	140 [14]	25,000 [15]	321	-	10,415,810	74,399	417	-	-	2018	[37]

Table A1. *Cont.*

Country	Number	Members of ECs	Members Per One EC (Mean)	Approximate HHs Number [1] Consuming Electricity Generated/Supplied [2] by ECs	Country Total Population	Proportion of Population Per One EC	Proportion of Population Involved in ECs, Citizens/EC Member	Proportion of the Population Consuming ECs Produced Energy [3], Citizens/Consumer	National/Regional Federation of ECs or Sector-Builders	Status Year	Source
Switzerland	289	152,036 [16]	526	-	8,697,720	30,096	57	-	VESE (solar coops), ASEC (Swiss Association for Citizen Energy)	2016	[31,52]
United Kingdom	495	58,000	117	174,000	67,326,570	136,013	1161	168	Community Energy England, Community Energy Wales, Community Energy Scotland, Energy4All, Sharenergy, and Communities for Renewables	2021	[56,81]
Total/Average	**3931**	**899,811**	**844**	**3,585,573**	**489,373,240**	**124,112**	**532**	**59**	-	-	-

[1] Calculations based on the average EU household consisting of 2.3 members (residing in a single dwelling) consuming 3.7 MWT of electricity per year in 2019 [82]. [2] For ECs with the main business activity being the generation of energy, we used energy generated by their plants. For ECs with the main business activity being retail although owning shares in generation plants, we used the energy generated. For ECs purely providing retail service, we used energy supplied to the clients. ECs with the main business activity being the provision of services were not included. [3] Calculated by dividing "Country total population" on the outcome of multiplication of "Estimated HHs number consuming electricity generated/supplied by ECs" and 2.3 (which is an average number of household members in the EU in 2019). [4] A total of 286 energy cooperatives reported by Wierling et al. (2018) [41] predominantly district heating + 60 energy communities created since Austria transposed EU Directives and established a new legal organizational form mapped by Austria Coordination Office for Energy Communities. [5] Info just for 38 ECs (19 Wallonia and 19 Flanders, 3 Flanders is not available). [6] Info corresponding to 38 co-ops for which generation numbers are available. [7] Included only district heating and wind cooperatives. [8] Including functioning as well as development stage, without emergence stage. [9] Reported by the Énergie Partagée, 930,915 people divided by 2.3 (average number of ppl per HH). [10] Available data for only 5 ECs included. [11] Total of 65 historical in Alpine arc, 28 new ECs not corresponding to Italian regulation, 26 new ECs emerged after 2020–2021 corresponding to Italian regulation. [12] Only members of 65 historical and 11 new ECs included, for ECs emerged after 2020–2021 data are not available. [13] Only data for 65 historical and 11 new ECs included. [14] Total of 78 wind cooperatives, 32 eco-villages, the rest are solar, hydropower, and district heating. [15] Only wind. [16] Approximated calculation based on numbers reported by 129 ECs participated in survey by Rivas et al. (2018) [31]. Membership of 129 ECs is 68,416; number for 289 ECs was approximated using data from 129 ECs.

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